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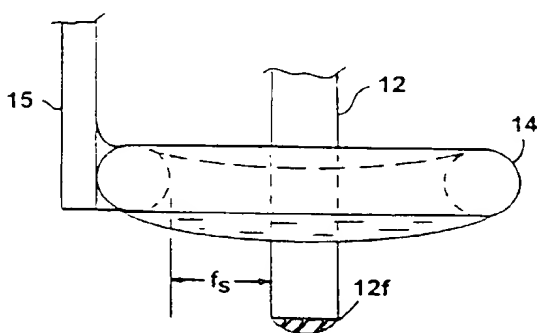
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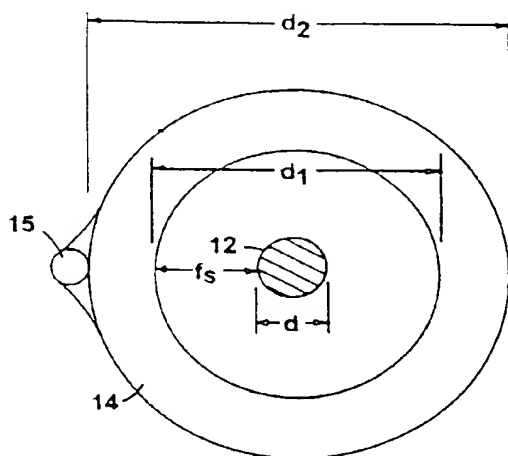
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(54) Title: CLEANING DEPOSIT DEVICES THAT GENERATE MICROARRAYS



(57) Abstract: An apparatus for depositing an array of spots on a receiving surface includes a fluid source, a deposit device that includes a drop-carrying surface, and a cleaning device. The deposit device and a fluid source are cooperatively arranged to deposit a spot (usually created by a drop) on a receiving surface. The cleaning device is constructed and arranged to clean the drop-carrying surface by employing a flow of cleaning fluid or another cleaning matter such as small particles.



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CLEANING DEPOSIT DEVICES THAT GENERATE MICROARRAYS

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Background of the Invention

The invention relates to devices and systems that deposit small quantities of fluid upon substrates in a precise manner and in arrays of desired density and consistency, and especially to cleaning such systems and other equipment in the laboratory. The invention is useful, for instance, in preventing cross-contamination when carrying out reactions, in providing accurate overlays of deposits, and, in particular, in preparing microscope slides and membranes with biological materials, for instance, microarrays for drug delivery, gene research and clinical use.

In well developed biological analytical technology, and in recently developed biochip technology, creation of dense arrays of fluorescently labeled micro-organisms and DNA assays in a two dimensional field is performed. It is desirable to place the arrays on a conventional microscope slide, or other carrier and to create many such slides simultaneously in a manufacturing process.

For biochip technology to proceed to complete fruition, as well as to improve the application of previous analytical techniques, economical instruments and systems have been needed that can, without contamination, rapidly and accurately create the dense array of objects over a large field portion of a glass microscope slide or a slide-like member that occupies an area approximately 22 mm wide and 50mm long of a slide that is nominally 25 mm x 75 mm.

In the deposition upon a microscope slide of discrete, minute quantities of a large variety of fluid materials, the volume deposited at a discrete spot typically may be from a few pico liter to a fraction of a micro liter, depending upon the application. The devices for forming such deposits are small and may have high surface energy. The biological material carried in this fluid can range from

a few strands of short oligonucleotides in a water solution to a high concentration of long strands of complex proteins.

The properties of these fluids vary enormously. Some are akin to water while others are far more viscous, resembling
5 a light oil or honey. The range of fluids that may be employed also exhibits wide differences in other properties that make clean up difficult.

Such a large range of property variations in fluids of interest has caused difficulties for any single type of
10 process to operate over a wide range to produce the desired array of deposits, to maintain such instrument clean and avoid contamination of the deposited array, the used biological material and various fluids used for deposition.

15 Summary of the Invention

One purpose of the invention is to provide a technology deposition of very small drops of fluids, and arrays of drops, e.g. drops that form spots of less than about 375 or 300 μm diameter, and in important cases, very
20 much smaller than that, deposited at correspondingly high densities. As used in this application, the term fluid "drop" refers to a very small quantity of fluid or fluid including solid material, and not to any particular shape of the fluid volume. When depositing an array of drops, it is
25 important to avoid contamination in progressing from work with one material to another as well as contamination of the source material.

The present invention relates to methods and apparatuses used for depositing a biological or other
30 material on a receiving surface and creation of an array. The deposited array is suitable for sample acquisition, preparation microscopic analysis, reaction or other purposes. The deposited array is useful in a variety of biological applications some of which are described in U.S.
35 Patents 4,965,188; 5,143,854; 5,384,261; 5,856,174, which are incorporated by reference.

According one aspect, an apparatus for depositing an array of spots on a receiving surface includes a fluid source (or source means), a deposit device that includes a drop-carrying surface (or deposit means), and a cleaning
5 device (or cleaning means). The deposit device and a fluid source are cooperatively arranged to deposit a spot (usually created by a drop) on a receiving surface. The cleaning device is constructed and arranged to clean the drop-carrying surface by employing a flow of cleaning fluid (or another
10 cleaning matter such as small particles).

The apparatus may include additional optional elements discussed below and/or shown in the drawings. The cleaning device may include a fluid jet constructed and arranged to blow the cleaning fluid. The fluid jet may be
15 constructed and arranged to blow the cleaning fluid at least partially along a length of the deposit device toward the drop-carrying surface. The drop-carrying surface may be located at least partially within a confinement chamber.

The deposit device may have a pin-like structure
20 with the drop-carrying surface disposed in a distal end of the pin-like structure. The drop-carrying surface may have a diameter less than 375 micron, preferably less than 300 micron, preferably between about 15 and 250 micron. The pin-like structure may include sides that intersect with an
25 end surface that defines a rim of the drop-carrying surface.

The apparatus may include one or several fluid sources. The fluid source may include or be used with a mobile supply device, associated with the deposit device, and arranged to supply material for deposition of the array
30 of spots. The fluid source may include or be used with a mobile local supply device arranged to move partially with the pin-like structure. The deposit device and the mobile supply device may be movable together to the cleaning device in response to a control system.

35 The mobile local supply device may include an annular member through which the deposit device operates by

a relative motion of the drop-carrying surface, and the cleaning device may include a nozzle for directing a flow of the cleaning fluid past the annular member and the drop-carrying surface.

5 The apparatus may include one or several cleaning devices. The cleaning device is constructed and arranged to deliver the cleaning fluid at least partially to the mobile supply device or the mobile local supply device. The mobile local supply device includes a ring-like structure located
10 near the drop-carrying surface. The cleaning device may be constructed and arranged to deliver the cleaning fluid at least partially to the ring-like structure and the drop-carrying surface.

 The apparatus may further include a drying device
15 constructed to discharge drying fluid. Alternatively, the drying device is included in the cleaning device and is constructed to discharge drying fluid using the fluid jet used for cleaning. The fluid jet may have various designs and may include a circular nozzle constructed to emit a
20 conical flow of the cleaning or drying fluid, or may include an annular or other nozzle

 The apparatus may further include a reservoir for receiving the cleaning or drying fluid. A vacuum pump or another pumping device may be associated with the reservoir.
25 The reservoir receives the cleaning or drying fluid emitted from the fluid jet. The fluid jet or nozzle may be located inside a containment chamber or outside the chamber. The pump may create a pressure differential for removing the cleaning or drying fluid emitted from the fluid jet.

30 The apparatus may include two or more fluid paths associated with at least two fluid reservoirs and connectable to the fluid jet. The apparatus may be associated with a control system arranged to control a flow velocity of the cleaning fluid. The apparatus may be
35 associated with a control system arranged to select a type of the cleaning fluid. The control system may be arranged

to select the type of the cleaning fluid at a source location. The cleaning fluid is selected from one of the following compressed gas, high-pressure liquid, aerosol and heated gas.

5 The apparatus may include four or more deposit devices and a mechanism for moving each deposit device independently toward and away from the receiving surface to deposit respective drops at respective deposit locations on the receiving surface. Alternatively, the mechanism may
10 move the deposit devices simultaneously, relatively, toward and away from the receiving surface to deposit respective drops at respective deposit locations on the receiving surface. The deposit devices may be mounted on a common support that is driven by a common driver to deposit
15 respective fluid drops on the receiving surface. These deposit devices may be associated with respective storage rings, wherein the storage rings are mounted on a common storage support driven by a common storage drive.

 The apparatus may include a mobile fluid storage
20 device that is movable relative to an array of deposit locations, wherein the mobile supply device is constructed and arranged to resupply the deposit device at various locations along the array. Preferably the deposit device and the mobile storage device are constructed to supply
25 drops to the deposit device in the immediate vicinity of the deposit locations for respective drops and preferably being coupled for transverse motion relative to the array and decoupled for movement of the deposit device toward and away from the receiving surface.

30 According to yet another aspect, an apparatus for depositing fluid dots on a receiving surface in an array (e.g., for microscopic analysis reaction and the like) includes a deposit device and a fluid source which are cooperatively related to enable the deposit device to
35 precisely size a drop of fluid of small diameter on a drop-carrying surface of the device, transport mechanism for

positioning the device at a precisely referenced lateral position over the receiving surface and drive mechanism for moving the deposit device, relatively, in deposition motion toward and away from the surface, the apparatus adapted, by repeated action, to deposit the drops of fluid precisely in a desired array, and then to proceed to a cleaning station where the instrument is cleaned and then to a resupply station for further action with regard to other materials, free of contamination, preferably the apparatus being computer controlled.

Preferred embodiments have one or more of the following features.

A cleaning station comprises a fluid jet arranged to blow down along the length of the deposit device toward its drop-depositing end, the jet and device being within a confinement chamber.

The deposit device is a pin or pin-like structure having an end surface that carries the fluid drop, preferably the pin or pin-like structure having sides that intersect with the end surface to define a sharp peripheral drop-defining rim.

According to yet another aspect, an apparatus for depositing fluid drops on a receiving surface includes a deposit device and a fluid source which are cooperatively related to provide to a drop-carrying surface of the deposit device a precisely sized drop of fluid, and a cleaning system that effectively cleans the pin, the deposit device being a pin or pin-like structure having an end surface that serves as the drop-carrying surface, the pin or pin-like structure having sides that intersect with the end surface to define a sharp peripheral drop-defining rim.

Preferred pins or pin-like structures have an end surface that is generally flat and side surfaces that are cylindrical and smooth.

In many important cases, the fluid source is a mobile fluid storage device that is movable relative to an

array of deposit locations, the fluid storage device being constructed and arranged to resupply the deposit device at various locations along the array.

According to yet another aspect, an apparatus for
5 depositing fluid drops on a receiving surface, includes a deposit device and a fluid source which are cooperatively related to provide to the deposit device a drop of fluid, transport mechanism for positioning the deposit device over
10 a receiving surface and drive mechanism for moving the deposit device, relatively, in deposition motion toward and away from the receiving surface, the apparatus adapted, by repeated action, to deposit the drops of fluid in a desired array, the fluid source being a mobile fluid storage device that is movable relative to the array of deposit locations,
15 the fluid storage device being constructed and arranged to resupply the deposit device at various locations along the array, the system adapted to effectively clean the instruments between changes of fluids.

In preferred embodiments employing a mobile storage
20 device, the deposit device and the mobile storage device are constructed to supply drops to the deposit device in the immediate vicinity of the deposit locations for respective drops, preferably the mobile fluid storage device and the deposit device being coupled for transverse motion relative
25 to the array and decoupled for movement of the deposit device toward and away from the receiving surface.

In many cases the mobile storage devices or mobile local storage devices are constructed and arranged to be replenished from a remotely located large reservoir. In many
30 cases a mobile storage device holds a volume of fluid having a free surface into which the deposit device is lowered and raised to obtain a fluid drop, preferably the mobile storage device being constructed to store a multiplicity of isolated fluid volumes in the wells of a multiwell plate, the
35 apparatus constructed to obtain its fluid from a selected volume of the plate.

In other important cases a mobile local storage device defines a generally annular fluid retention surface or ring (the term "annular" or "ring" being used to refer broadly to a member that has opposed, or adjacent, surfaces that can hold a mass of fluid between them by surface tension effects, accessible to a deposit device). and the deposit device is constructed to move within the annular retention surface from retracted to extended positions, in the retracted position the drop-carrying surface of the deposit device being retracted from the surface of fluid retained by the annular surface of the storage device, and in the extended position the drop-carrying surface of the deposit device being projected through and beyond the surface of the retained fluid. Advantageously, the cleaning device can cleans the pin and ring simultaneously.

According to yet another aspect, an apparatus for depositing fluid drops on a receiving surface in an array suitable for microscopic analysis, comprising a deposit device and a fluid source which are cooperatively related to provide to a drop-carrying surface of the deposit device a precisely sized drop, and a drive mechanism for moving the deposit device, relatively, in deposition motion toward and away from the receiving surface, the storage device defining a generally annular fluid retention surface, and the deposit device being constructed to move within the annular retention surface from retracted to extended positions, in the retracted position the drop-carrying surface of the deposit device being retracted from the surface of the fluid retained by the annular surface of the storage device, and in the extended position the drop-carrying surface of the deposit device being projected through and beyond the surface of the retained fluid, the relative position of the deposit device and the storage surface being adjustable so that at the cleaning station an optimal relationship for cleaning can be achieved.

In preferred embodiments, a member that defines an

annular fluid retention surface is associated with a driver that moves the member relative to the deposit device to a replenishment volume in which the member is immersed to receive a supply of fluid, and to a cleaning position when
5 the system arrives at the cleaning station.

In certain preferred embodiments the deposit device is a pin or pin-like structure e.g. having one or more of the features described above, the pin or pin-like structure being mounted within the confines of an annular fluid
10 retention surface and arranged to move axially relative thereto.

The apparatus of any of the aspects and preferred embodiments described preferably include a control system adapted to control relative movement of the deposit device
15 to a depositing relationship to the receiving surface and a cleaning relationship to the cleaning system.

According to yet another aspect, an apparatus for depositing an array of dots on a receiving surface, comprising a deposit device in the form of a pin or pin-like
20 structure having an end surface capable of precisely defining a small drop of fluid, a source of fluid for the deposit device, mechanism for moving the deposit device relatively over an array of spaced apart deposit locations of a receiving surface, mechanism for repeatedly moving the
25 deposit device, relatively toward and away from the receiving surface to deposit respective drops of fluid at selected deposit locations, a cleaning system, and a control system adapted to control relative movement of the deposit device between a resupply relationship to the source, a
30 depositing relationship to the substrate and a cleaning relationship to the cleaning system.

In embodiments in which the deposit device is associated with a mobile supply device that travels with it, the deposit device and mobile supply device are preferably
35 movable together to the cleaning system in response to the control system, preferably the mobile supply device being an

annular member through which the deposit device operates. Preferably the cleaning system has a nozzle for directing a flow of air past the annular structure, preferably a cleaning or drying station comprising a circular nozzle is
5 constructed to discharge a conical flow of fluid, preferably compressed air, high pressure liquid, an aerosol or heated air against a deposit device or mobile fluid source, preferably the deposit device being a pin or pin-like structure surrounded by a mobile reservoir in the form of an
10 annular member capable of holding a supply of fluid by surface tension effects, the nozzle flows directed to dislodge retained fluid, to clean or to dry the respective parts; in some cases, preferably a circular storage device is associated with a heater, e.g., an induction heater.

15 Preferably, each device to be cleaned has its own cleaning chamber to which it travels, for removal of previous fluid, washing and drying in a so-called "one stop shop".

In certain preferred embodiments of the various
20 aspects and features described, there are provided a set of at least two of the deposit devices, preferably many more, at least one fluid source for providing a drop of fluid on each deposit device, and mechanism for moving the pins together transversely over an array of spaced apart deposit
25 locations of the receiving surface, and to a cleaning station for the respective deposit devices, preferably there being at least four of the deposit devices comprising a deposit head. Preferably the apparatus includes mechanism for repeatedly moving each deposit device independently, or
30 mechanism for moving each deposit device simultaneously, relatively, toward and away from the supply device for resupply, the receiving surface to deposit respective drops at respective deposit locations on the receiving surface, and, optimally the cleaning station.

35 For simultaneous actuation, preferably two or more deposit devices are mounted on a common support, driven by a

common driver to deposit respective fluid drops on the receiving surface. In cases in which each deposit device is associated with a respective storage ring, the storage rings are also mounted on a common support, driven by a common
5 drive; preferably the spacing of the rings corresponds to the spacing of a multiwell storage plate into which the rings are immersed for resupply. In cases in which the deposit device is lowered directly into fluid and raised to obtain its drop, preferably the spacing of the deposit
10 devices corresponds to the spacing of wells of a predetermined multiwell plate, the multiwell plate being a mobile fluid supply that is constructed to accompany the deposit device across the substrate. In the case of supply rings or direct dipping of the deposit devices, preferably
15 the spacing corresponds to well-to-well spacing of wells of a 96, 192, 384, 864 or 1536 well plate, or a spacing of 9 mm or a submultiple of 9 mm. Likewise in this case and others, the deposit devices register with discrete cleaning stations for the individual elements, in which preferably, high speed
20 fluid flow is directed toward the instruments being cleaned, but in a direction away from the work environment. Preferably, the high speed flow induces air flow from the work environment along the device being cleaned to create a negative pressure condition in the work environment and
25 avoid backflow of contaminants from the containment chamber.

The apparatus of any of the foregoing is preferably constructed to mount a number of microscope slides or slide-like structures to serve as the receiving surface, and a control system is constructed and arranged to deposit drops
30 of fluid in selected locations on the slides or slide-like structures, preferably the fluid source comprising a source of biological fluid.

Preferably, for depositing fluid drops in a dense array of mutually isolated dots, a deposit assembly is
35 constructed to travel to a cleaning station, and comprises a fluid source for repeatedly providing a discrete drop of

fluid on the tip of the deposit device, mechanism for moving the device relatively over an array of spaced apart deposit locations of a receiving surface, mechanism for repeatedly moving the device, relatively, toward and away from the
5 receiving surfaces to deposit respective dots at respective deposit locations on the surface, preferably the fluid source being a mobile fluid storage device separate from the deposit device, which is generally movable over the array of deposit locations, the fluid storage device being
10 constructed and arranged to resupply the deposit device at various locations with respect to the array.

In certain preferred embodiments of this aspect also, the deposit device is a slidable pin or pin-like structure constructed and arranged to dip into a volume of
15 fluid carried by a mobile storage device, preferably the storage device being constructed to store a multiplicity of isolated fluid volumes, the apparatus constructed to move the supply device relative to the deposit device to select the fluid to be deposited, preferably the storage device
20 being a 96 well plate or a plate having a multiple of 96 wells, and also preferably including at least one driven stage for moving a selected well of a mobile multiwell plate into registry with the deposit device under computer control for enabling motion of the deposit device to dip into and
25 out of the preselected well to provide a drop of the selected fluid to the device.

According to yet another aspect, a deposit apparatus includes a multiplicity of deposit devices as described, mounted for motion together in response to a common
30 actuator, preferably the deposit devices comprising deposit pins or pin-like structures adapted to enter respective cells of a cleaning station of the kind described above.

According to yet another aspect, an apparatus includes a mobile fluid storage device separate from a
35 deposit device and generally movable over an array of deposit locations, the fluid storage device being

constructed and arranged to resupply the deposit device at various locations with respect to the array, in one case, preferably the mobile fluid storage device being constructed to store a multiplicity of isolated fluid volumes, the
5 apparatus constructed to move the mobile storage device relative to the deposit device to select the fluid to be deposited, preferably the deposit device being a pin or pin-like structure constructed and arranged, under computer control, to dip into a cleaning station periodically and in
10 operation, dip into a selected volume of fluid carried by the mobile fluid storage device, preferably the mobile fluid storage device being a multiwell plate having 96 wells or multiples of 96 wells, or a spacing of 9 mm or a submultiple of 9 mm and preferably the apparatus including a driven
15 stage for moving the fluid storage device into registry with the deposit device under computer control for enabling dipping of the deposit device into a preselected fluid volume; in another case preferably the mobile storage device is an annular ring that retains a supply of fluid by surface
20 tension.

The present invention also features the method of use of all the described apparatuses. In the various methods, preferably the receiving surface is fragile, or soft, preferably the receiving surface is porous or
25 microporous or fibrous, preferably comprising nitrocellulose, nylon cellulose acetate or polyvinylidene fluoride or a gel, preferably the member defining the soft or fragile receiving surface being mounted on a rigid carrier member, either directly or upon an intermediate soft
30 or resilient buffer member.

Preferably the method is employed to deposit a fluid selected from the group of biological fluids described in the specification, preferably the material being a biological probe or a chemical for reaction with biological
35 material, a fluorescing material, an ink, dye, stain or marker, a photoactive material, or a varnish or an

encapsulant or an etchant, or a cleaning or neutralizing agent.

According to yet another aspect, the method of depositing a biological fluid with a pin (or a pin-like structure) comprising supporting fluid within a ring (or a ring-like structure) by surface tension, and moving the pin (or pin-like structure) through the ring (or the ring-like structure) in the manner that a relatively small drop of the fluid is held at the end of the pin (or the pin-like structure) by surface tension and deposited on a receiving surface, and moving the structures to a cleaning station.

Brief Description of the Drawings

In the Figures:

Fig. 1 depicts a spotting system employing the deposit action depicted in Fig. 1A, combined with a cleaning station and a central supply of fluid specimen.

Fig. 1A depicts a mobile sub-reservoir that travels from one deposit position to another with a separate deposit device illustrated as a deposit pin.

Fig. 2 depicts a spotting system employing the deposit action depicted in Figs. 2 and 3, combined with a cleaning station and a central supply of fluid specimen.

Fig. 2A is a side view and Fig. 2B a top view of a deposit head, comprising a deposit pin and an annular sub-reservoir through which the deposit pin operates, while Figs. 3A-3D depict a sequence of stages of the deposit action of the head of Fig. 2A.

Fig. 4 is a perspective view of an assembled deposit pin constructed according to Fig. 4A combined with a respective supply ring.

Fig. 4A is a diagrammatic side view of a combination of a deposit pin and a cooperating support that provides lateral constraint of the pin.

Fig. 5 illustrates an arrayer system, employing a group of assemblies of Fig. 4 constructed for commercial

use.

Fig. 6 is a perspective view of a machine for depositing dots of biological fluid in dense array upon a series of microscope slides.

5 Fig. 6A shows features of the control system software and method for conducting the deposit and cleaning action.

Fig. 7 depicts a station for removing liquid, washing and drying the pin and ring at one location.

10 Fig. 8 is a perspective, partially cut-away view of a preferred cleaning module while Fig. 8A is a magnified view of a portion of Fig. 8.

Fig. 9 is a view of a preferred relationship of a pin and associated mobile reservoir ring while Fig. 9A
15 illustrates certain dimensions other embodiments of Fig. 9.

Fig. 10 and 10A are side and bottom constructional views of the module of Figs. 8 and 8A.

A. Preferred Embodiments

20 In preferred embodiments a deposit pin D of small cross-section is employed with a mobile fluid reservoir to which the pin is repeatedly exposed, the pin being sized and shaped to define and retain on its tip a drop of fluid from the reservoir, the drop containing only enough material to
25 deposit a single dot. The fluids and the resultant dots permissibly exhibit a wide range of properties such as viscosity, evaporative characteristics, surface tension, wettability, surfactant characteristic, dynamic contact angle and free surface energy.

30 Presently we prefer that the rim of the tip of the pin be "square", i.e. that, in profile, the end surface of the tip of the pin be substantially at a right angle to the side surface of the pin, and that the pin side surfaces be smooth. Preferably the pin is round in transverse cross-
35 section, though it may be of other shapes.

It is found that arrays of fluid dots between about

20 microns to 375 microns can be deposited using biologic fluids of conventional concentrations, by employing deposit pins that have, in their tip regions, a wire or wire-like geometry of diameter (true diameter or cross-section dimension) between about .001 inch (25 microns) and .015 inch (375 microns). The smaller tips, i.e. tips smaller than .012 inch (300 microns) are referred to here as "microtips". A preferred range of tip sizes is between 50 microns and 250 microns.

10 Tightly packed arrays of deposited dots of fluid can be achieved, i.e. arrays with center-to-center spacing between dots of less than three times the dot diameter, often only twice or one and one half times the dot diameter.

 Provision of a suitable mounting and drive of the deposit pin enables a low and predictable contact force upon the receiving substrate (a "soft landing") despite variations in the height of the substrate, e.g. due to variations in thickness of microscope slides or slide-like members upon which the fluid dots are applied. Superior results can be obtained by controlling the deposit pin force upon the substrate to less than the order of one gram, or 0.5 gram, preferably about 0.3 gram.

 The systems enable spotting of, e.g., a full set of 40 microscope slides with 10,000 spots per slide, a process that may require a few hours to a few weeks, depending upon the number of pins operating simultaneously in one head. The instrument may operate unattended for many hours at a time.

 In preferred mechanical systems, the pin is compliantly mounted and responds to resistance force transmitted to the pin by the fluid or mechanical contact with the substrate, so that the tip of the pin stops despite overtravel of the driver. Different deposition systems are described in the PCT application PCT/US99/00730 (WO 99/36760), entitled "Depositing Fluid Specimens On Substrates, Resulting Ordered Arrays, Techniques For

Analysis Of Deposited Arrays", which is incorporated by reference.

B. Mobile Fluid Reservoirs

5 And Interaction With Deposit Pins and Cleaning Station

For making a succession of deposits of the same fluid, as when preparing a number of microscope slides or membranes or providing redundant deposits on a single substrate, a mobile sub-reservoir, periodically re-supplied
10 from a stationary central supply, travels with a deposit device to be near the deposit locations.

As illustrated in Fig. 1A, a deposit head comprises the deposit pin P and the sub-reservoir SR which is sized to contain sufficient sample to enable deposit of a number of
15 dots before being resupplied.

After deposit of drop F at target S, e.g. on a microscope plate R or a plate carrying a delicate or soft membrane, the assembly proceeds to plate R_1 , pin P is resupplied with drop F_1 by being dipped into and raised from
20 the accompanying sub-reservoir SR, the new drop is then deposited at target point S_1 at plate R_1 , and so on.

The system is especially useful for preparing a number of microscope slides or membranes. The central fluid supply CS advantageously is a multiple well plate as
25 conventionally used in microbiology, such as a 96 well plate. Cleaning and drying station CL is also provided. The deposit sequence includes moving the assembly of deposit device and mobile sub-reservoir under computer control through cleaning and drying station CL, thence to central
30 supply CS at which the sub reservoir SR is supplied with a selected fluid sample, e.g. from a selected well of a 96 well plate. Then the group moves over a series of receiving surfaces $R-R_n$, for deposit of fluid dots at selected locations on each, also under computer control. This
35 sequence is repeated a number of times, with controlled selection of different fluid samples (from, e.g., different

wells of the central supply CS) for respectively different locations on the plates R or other receiving surfaces. Data that correlates locations with respective specimens is recorded in memory and used in subsequent scanning or
5 reading.

The technique of using a deposit tool that accurately sizes each individual drop, such as the deposit pin with square rim profile at its microtip, combined with a mobile local sub-reservoir that accompanies the tool and
10 carries a volume sufficient to supply a sequence of deposits, has a number of important advantages. The technique, based on small motions, saves time in avoiding repeated travel to a central supply; it avoids evaporation losses of long travel, so that the drop created can be very
15 small and the deposited array very dense; and the dots can be kept consistent in size and concentration or biological content across the array of dots being deposited. The time overhead involved in cleaning, transporting and picking up the specimen is kept small so that, overall, deposits can be
20 made very fast, inexpensively and have desired small size.

In this way a large number (for instance ten to one hundred) identical microscope slides or membranes can readily be prepared by repeated motions over an array of the slides or membranes. Each substrate can carry dots of many
25 different fluids based upon resupply of the sub-reservoir from different wells of a number of multiple well plates introduced to the system, and cleaning between changes of fluid.

The sub-reservoir and the deposition device are
30 decoupled, in being movable relatively to one another for resupply and for deposit, as well as being coupled or at least coordinated, to move laterally over the receiving surface to produce the series of deposits. The sub-reservoir can move into a resupply position, e.g. by
35 immersion into a well, or under a suitable pipette. It can be made to hold sufficient fluid in excess of that required

for the sequence of deposits, or to expose a sufficiently limited evaporative area, that concentration of the substance of interest in the fluid is not substantially affected by evaporation during the multiple deposit
5 sequence.

Thus we have described deposit devices constructed to precisely define a single fluid drop of desired size, obtained from a mobile sub-reservoir, deposit the drop at a precisely positioned, discrete location and return by local
10 movement to the sub-reservoir for another drop. In the preferred embodiment of Figs. 1 and 1A an axially reciprocable deposit pin is employed for this purpose in conjunction with an accompanying sub-reservoir in which the pin is directly dipped. Alternatively, a probe that dips
15 into a local sub-reservoir as by coordinated rotational or translational motions of a wire or pin, can accomplish this action, as can other designs.

Referring now to Fig. 2A and 3A-D, another preferred mobile sub-reservoir is an annular reservoir ring 14 which,
20 as depicted, holds fluid between its interior opposed surfaces by surface tension effects.

Deposit pin 12, having a sharp rim 12F at its tip, of diameter d selected to produce the desired size of the deposited dot, is mounted in axi-symmetric relation to sub-
25 reservoir ring 14. Ring 14 has an internal diameter d_1 significantly larger than the pin diameter such that fluid space f_s exists between the pin and the inner surfaces of the ring. The outer diameter d_2 of ring 14 is sized smaller than the well of a central supply plate, so that the ring
30 can be immersed in it for supply.

During the deposit sequence of Figs. 3A-3D the ring 14 is held stationary by its support rod 15 while the deposit pin 12 is moved by an associated driver D through a sequence of vertical positions. In the start position, the
35 end 12D of pin 12 is drawn above the lower surface of the retained fluid R_f held by surface tension effects between

the internal surfaces of ring 14. This is shown in Fig. 3A.

(The pin, for illustration, is shown withdrawn fully above the retained fluid R_f , although that is not necessary.)

Comparing Fig. 3A with Fig. 2A, by downward movement
5 of the pin tip from above the lower surface of the retained fluid R_f (Fig. 3A), to below that surface (Fig. 3), the tip of the pin, with its sharply defined rim, picks up from the retained fluid R_f a precisely sized volume of fluid as drop F. The drop is then deposited in the sequence shown in
10 Figs. 3C and 3D. Interestingly, as the pin penetrates the meniscus, surface tension pulls the fluid laterally from the pin with the result that a much smaller amount of fluid can remain on the end of the pin than in the case in which a pin is dipped and then raised from an open supply. In many
15 cases this volume-limiting action is highly desirable, as it permits monolayers or at least very thin spots to be deposited, saving material and providing a uniform fluorescing mass that enables more accurate reading to occur.

20 At the resupply position, see Fig. 2, the annular ring 14 is moved downwardly by its support rod 15 for immersion in the well of the supply plate while the pin 12 remains stationary at a higher elevation, or it may assist in the resupply action, by being present within this ring
25 with its end, for instance, flush with the bottom of the ring, as shown in Fig. 2.

At cleaning and drying stations the lower surfaces of the pin 12 and ring 14' are vertically at the same level.

At a washing station the ring and pin may both be
30 subjected to reciprocation in the same or opposite vertical directions to assist the cleaning process.

The multipurpose cleaning station illustrated in Fig. 7 is sized to receive deposit pin 12 and supply ring 14. It has an annular nozzle 200 directed inwardly against
35 the pin and ring to subject the parts to a conical flow from fluid sources such as compressed air, pressurized liquid and

aerosols. The flow is directed past the parts 12, 14 to a trap having disposable filter 202 that intercepts material being removed from the parts. The trap may be associated with a vacuum pump. As shown, nozzle 200 is associated with
5 a secondary air path 204 to enable nozzle flow to induce a flow of secondary air when desired.

The system of Fig. 7 is useful to remove sample liquid from the parts, to effect cleaning, and to dry the parts. For example the pin and ring are first exposed to
10 one or more simultaneous or successive fluid currents or blasts of continuous or pulsed flow that blow remaining sample fluid from the parts and into the trap. Subsequently, a fluid stream of liquid or air may expose the parts to cleaning fluids such as liquid streams or aerosols
15 containing water-borne detergent. This is followed by rinsing with pure water from the nozzle. Following washing, an air current from the nozzle, supplemented by induced air flow 204, can dry both pin and ring, in which case the air streams may be heated.

20 There is an advantageous relationship of pin and ring for resupply of the ring. When the ring is immersed in selected well W of a multiwell plate, Fig. 2, the pin is present within the confines of the ring, to help the ring pick up the fluid. The surface tension properties
25 effectively cooperate to compete with the surface tension effects of the walls of the well that resist removal of small quantities of the fluid. In the presently preferred relationship, the bottom tip surface of the pin is substantially aligned with the lower surface of the ring.
30 Withdrawal of the assembly from immersion in well W withdraws a desired amount of fluid, pendent as a large meniscal drop, bounded by the pick up ring. This quantity, protected and supported by the ring, is then available for deposit in tiny drops by repeated projection of the pin
35 through the ring.

The sub-reservoir ring may have various advantageous

forms such as axially adjacent circular rings, multi-turn helical shapes, closed cylinders, open rectangular rings, open "U" shaped structures, etc. Thus the term "ring" or "annular ring" as used generally refers to any closed or partially closed structure that, through surface tension effects between adjacent or opposed surfaces, supports a volume of liquid in a space through which a deposit device such as deposit pin 12 can operate. The size of the opening or bore of the ring, as well as the size, for instance, of wire or ribbon that forms the cross-sectional shape of the ring is selected in relation to the properties of the fluid (e.g. viscosity and surface tension), the number of deposits to be made from a given fluid charge in the reservoir ring, and the size of the deposit pin that is to move through the ring.

The size and shape of the deposit pins that cooperate with these and other sub-reservoirs also vary depending upon the application. It is possible to employ pins of various transverse cross-section, e.g. square or hexagonal or even rectangular or oval cross-section of equivalent area to round cross-section pins. Especially for small dots, the pins may advantageously have stepped transverse cross-sections, e.g. may have an extremely small cross-section at the deposit end, to size the deposited drop, stepped to a larger cross-section in the main body, for providing structural stability.

For implementing the broad concept of a local, mobile supply, other techniques than those shown can be employed. An example is a large dip rod, an enlarged version of a deposit pin, from which a large drop depends, which travels with the pin and is visited by the pin by a suitable motion, such as rotation. Such respective dip rods and other devices may be provided cleaning stations similar to that shown.

C. Operating Systems

Some advantageous, novel operating systems that implement the foregoing principles will now be described.

DIP & DOT SYSTEM

5 The mobile reservoir shown in Fig. 1 can be a multi-well plate. Under computer control, an appropriate X,Y stage brings the chosen fluid resupply well in alignment under the pin. The pin is then controlled to descend, make contact with (dip into) the reservoir fluid and rise, taking
10 a small amount of fluid in the form of a pendant drop.

The pin is raised sufficiently to permit the pin and reservoir to separate e.g. by computer controlled sideways movement of the reservoir, freeing the pin to descend unobstructed to deposit its small fluid drop on the targeted
15 location on the substrate.

With appropriate transport motions of pin and multi-well supply, the process is repeatable at each location where a sample of the selected fluid is desired, the fluid in the proper well being repeatedly brought into alignment
20 with the proper pin for resupply and deposit in the desired location by computer control. Each time a pin is commanded to receive a fluid from a well different from that of its previous command, the pin is moved by computer control to liquid removal, cleaning and drying station CL, to prevent
25 contamination of the source or the target.

For efficient operation, a multiplicity of pins may be used at spacings that match the pattern of wells, enabling each pin to reach inside a separate well of the multiple well reservoir such as a 96 well plate or a 384
30 well plate, as are known in the field of biochemistry and analytics.

The pin assembly and its driving mechanisms are preferably mounted on a precision XY gantry as they require good positional accuracy. The multiple well plate may be
35 provided with two degrees of freedom in a plane parallel to the deposition plane and can be indexed under the pin

assembly on a separate structure. Because of the relatively large size of the wells, the translation assembly for the plate may have lower positional accuracy than that of the pin. In some cases the multi-pin assembly and the mobile
5 multiwell reservoir share the same X,Y gantry to advantage.

Under computer control, the multiwell reservoir separates in the Y direction from the pin assembly and the Z stage is actuated to cause the pins to form deposits upon substrate R. Then, the multiwell reservoir moves under the
10 raised pins into appropriate alignment, employing both Y_2 and X_2 motions under computer control. By Z motion the pins P_A dip into the commanded wells for resupply. The pins rise again, the multiwell reservoir moves laterally with Y_2 motion out of the way and the deposit process is repeated at
15 new targeted X,Y location of the pins on substrate R or R_1 .

While this mobile reservoir technique is useful with pins of any construction, the advantage of high accuracy of the linear motor indexing system is enjoyed when the pins are constrained in space to a highly accurate repeatable
20 position relative to their carrier, with the high density pin arrangements made possible by the structures shown. Advantage is also taken of the positional accuracy in respect of cleaning. The pins are moved to station CL, Fig. 1, and enter respective holes using the ganged actuator or
25 individual actuators that drive the pins in supply and deposit action.

MULTIPLE PIN PATTERNS

In the preferred embodiments, two rows of 4 or more
30 pins P, preferably constructed according to Fig. 4A are spaced apart in a 9 mm square grid pattern matching the spacing of the wells of a 96 well plate. This permits transport of fluid from all 96 wells, 8 wells at a time to an assembled array of microscope slides, and directs the
35 composition of 8 spaced apart blocks of approximate dimension each 8 x 8mm on each slide, covering in total

approximately 18 x 54 mm sq. Each pin deposits in a respective one of the 8 blocks simultaneously with a single actuation of the Z drive. The head repeats the action on each of the set of slides with the same fluid, and is then
5 cleaned to be ready for fluid from different wells. The same pin may be used to deposit the same fluid at a number of directed positions in a given block, and/or upon the corresponding block of a number of slides each having the set of 8 spaced apart blocks, the deposits on the slides
10 being much closer than the spacing between wells. By following an appropriate sequence, all wells may be visited by respective pins. Actually the dot size in practice is much smaller than illustrated and dot density much greater, e.g., with as many as 50,000 or 100,000 dots carried by a
15 single microscope slide.)

In a similar preferred embodiment, a grid of 12 pins has 2 rows of 6 pins each, again spaced apart in a 9 mm square grid pattern to match the spacing of the wells of a 96 well plate. This arrangement permits the transport of
20 fluid from all 96 wells, 12 wells at a time, and directs the composition of 12 spaced apart blocks of approximate total area 18 x 54mm sq. Similarly, 48 wells can be addressed simultaneously when working with a 384 well plate, having wells spaced 4.5 mm. Other plates can also be used in a
25 similar way.

With either arrangement, or in the case of many more pins, the method is performed under computer control to form a more densely packed array of fluid dots than that occurring in the multiwell plates, e.g. arrays of 20 micron
30 to 375 micron diameter dots with similar spacing between dots, using all fluids in the plate.

Just as the pins are located on 9mm centers, the square arrays themselves are distributed on 9mm centers over the face of the substrate. By following an appropriate
35 pickup sequence by repeated samplings, all wells are visited, the pins being conveyed under computer control to

the cleaning station between changes of fluids. The contents of the multiwell plate or a number of plates are thus distributed from the low density distribution of wells in multiwell plates to high density arrays.

5 Similarly, again using 9mm pin spacing, with two rows of 6 pins each, a sequence of samplings from the wells under computer control collects samples from all wells and uniquely distributes them as high density array deposits in 12 squares on the microscope slides or other substrate.

10 The benefit of such groups of pins is to create a large number of deposited dots simultaneously on one or many microscope slides or substrates. This can substantially reduce the time and cost required to create high density arrays.

15 The assemblage of pins on a 9 mm square grid can also be used to transport fluid from plates with well spacing constructed on a square grid that is based on sub multiples of 9mm, such as plates with 384 wells or 864 wells or 1536 wells, etc. The high accuracy of the computer
20 controlled gantry system enables accurate placement of the selected wells with respect to the pins, and the pins with respect to the receiving substrate and the cleaning station.

 It is evident that using the same logic, pins can be assembled in denser constructions to fit plates with smaller
25 well spacings.

 The denser the array, the tighter the location tolerances for the location of each small dot. The systems of laterally constrained deposit pins described in the PCT Application PCT/US99/00730 (which is hereby incorporated by
30 reference) are particularly capable of repetitive production of precise high density arrays. In the embodiment of 4A, the mounting tube, at its lower end, is shown to have been spun, to form a generally conical bottom ledge that, in interacting with a downwardly facing conical surface of the
35 pin, tends to center the pin. Using these principles, the mode of supplying the tips with fluid can be selected in

reference to the nature of the fluid as well as other operating parameters. A ring supply mode will now be described.

5

PIN & RING SYSTEM

The pin assemblies as shown in Fig. 4A and in Figures of the cited PCT application can be used with a simple axial ring translation mechanism. As the fluid needs to be picked up from a rather large well, a sufficiently compact arrangement of multiple pins and supply rings is possible. Figure 4 shows the relationship of a pin and ring without their support or actuation mechanisms. Seen in Fig. 4 are supply ring 14, pin tip 12d, ring body 35 from which a support rod segment 15 extends to the ring 14, pin shaft 12b, the pin seat 13 formed on pin body 12a and pin guide 12g. Fig. 5 shows a set of eight such pin and ring assemblies. It is evident that any number can be assembled in this fashion. In Figure 5 one can see the pin holding structure, and the ring holding structure and their respective linear stepper motors Z_1 , and Z_2 that enable relative vertical motion. The Z_1 motion for deposit on a receiving surface preferably involves overtravel, the compliance of the deposit pins relative to the receiving surface, as provided by spring 22 in Fig. 4A, ensuring proper deposition over a range of surface heights. The respective supporting linear guide rails for X and Y motion provide a complete array-forming mechanism. Fig. 5 illustrates a commercial realization of the design which attaches to the Y stage linear motor of a deposit system.

30 Deposit pin 12 can also be mounted on a parallelogram, cantilever construction or as described in the PCT application incorporated by reference.

Figure 2 suggests a deposit cluster 28 of independently operated deposit pins, formed by a number of the deposit assemblies described in the Figures 2A, 2, 4 and 4A. These employ a number of independent drives D, one to

drive each pin and one to drive each ring in Z direction for picking up and depositing fluid, and sensors to indicate to the control electronics the position of the operative elements.

5 The cluster may step to a selected X or selected X,Y position, at which a number of different motions under computer control may be caused to occur, picking up and depositing fluid in any order at any location desired, and visiting the cleaning station as required. Such a cluster
10 constitutes a particularly versatile tool when employed with conventional microtitre plates.

 In such embodiments the aliquot carrier rings 14 and pins 12 are spaced in the cluster at 9mm center-to-center distances or multiples thereof to facilitate operation with
15 96 well plates (in which the wells are spaced at 9 mm on center intervals, with 8 rows of 12 holes). Higher density plates also employ this configuration and have the same footprint but employ more holes, 16 x 24, with hole-to-hole resistance of 9/2 mm, to provide ``384 plates''. The system
20 described can be employed with 96 and 384 well plates, as well as any arbitrary arrangement.

 The versatility of the cluster of independently operable deposit pins is illustrated by the following examples.

25 An array of sub-reservoir rings, e.g. set at 9mm center-to-spacing, may be indexed in X,Y direction along with their pins and the rings may be driven down (or dropped) simultaneously into respective cleaning cavities or for supply or resupply from four wells of a conventional 96
30 or 384 well plate, in an action similar to the systems previously described.

 After suitable indexing, the set of pins may be driven down simultaneously to form deposits at a corresponding number of places, in the same format as the
35 supply plate.

 Alternatively, during resupply, one sub-reservoir

ring may be dropped to pick up material from a selected well while all others remain in their passive positions. Then the cluster may be moved until the next ring arrives at the same well or another selected well, at which point it is
5 dropped to pick up its aliquot, and so on, so that all of the rings may have the same fluid from the same wells or different fluid from any selected wells.

The cluster 28 may be moved in X,Y direction between pickup or deposit actions of successive pins so that, e.g.
10 all of the pins deposit the same or different fluid on a single slide at selectable addresses or each pin addresses a different slide, but at a different location, or two pins address one slide and two another slide, or the deposits are made one on top of another, etc.

15 The operator may also choose not to have one or more of the devices operating.

Thus it is seen that dense clustering of independently operable deposit pins and rings can enable high speed, versatile operation.

20 Actuation of all aliquot carriers simultaneously by one actuator and all pins actuated by another single actuator, to provide a multiple pin head, realized with flexure-mounted pins is also possible. For example, using linear stage techniques, two rows of four pins at 9mm
25 spacing in both X and Y directions are all mounted on a frame which is reciprocated along a rail via a carriage by a single motor. This causes the eight pins to move simultaneously. Likewise, two rows of four cooperating rings 14 are mounted on a common ring support 124, with the
30 same spacing. The single support is driven via carriage by one motor.

Referring to cleaning stations CL in Figs. 1, 2 and 6, 6A and 7 and the detailed views, Figs. 8-10, a preferred cleaning and drying station for a set of pin and ring
35 assemblies for plain pins or other tools used in the environment, employs a corresponding set of venturi passages

in which respective pin and ring assemblies, pins or tools are introduced. This provides "one-stop" shopping for a set of cleaning conditions such as alcohol denaturing, cold water rinse, detergent wash, hot water rinse, hot air dry.

5 A supply plenum is fed with pressurized fluid of selected quality from an air compressor 90, nitrogen tank, etc. In one example compressed air is employed for all cases, into which are selectively introduced by controls suggested by valves 92, agents to create the respective aerosols of

10 water, soapy or detergent solution, alcohol, etc., followed by heated air for drying, as produced by the resistance heater in the air flow path.

CLEANING

15 High density microarrays require spotting tools with correspondingly small features. The smaller the features, the more difficult it is to clean and prevent contamination.

The downwardly directed set of venturi passages of Figs. 8 and 8A, to which the tools gain access by entering

20 from the top of the chamber, is a very effective means of cleaning in many ways. First, it produces high pressure cleaning; second it enables the selection of the temperature of the fluid or air without moving the pins or rings; and it can be very efficient. In certain cases, the high velocity

25 air may drag or accelerate washing fluid or may entrain abrasive elements, for instance beads of polyethylene or other material with the simple use of fluid under pressure to provide the energy for the cleaning.

From the point of view of infectious or dangerous

30 material, the benefit from this new mode of cleaning is that the contaminant will not escape into the working zone, such as the enclosed spotting area of the arrayer in Fig. 6. The enclosure ensures that the instrument is situated in a controlled environment. The flows of the venturi tubes are

35 arranged to have an educator or pump effect, drawing (i.e. entraining) air from the working zone and preventing

contaminating back flow from the cleaning chamber.

This type of cleaning is especially useful for the arrayer, but more generally has broader potential as a cleaning station for small instruments, in particular where
5 escape of contaminants is to be avoided, for instance in a hospital or food preparation setting. The jet is aimed down from the access portals at the to of the module, through which the devices to be cleaned enter. Because of the contained nature of the jet action one may employ very high
10 fluid pressure, high temperature and strong cleaning agents while the immediate environment is protected from contamination or disturbance. Thus adaptations of the principle provide a nearly universal cleaning tool for biological and other laboratories. The air jets enable
15 reaching surfaces to which access is difficult. The fluid agent or the cleaning agents are contained in all directions and do not escape. They do their work of cleaning while being contained and are retrieved and disposed of with little chance of escape.

20 The system comprises basically a containment chamber with entry portals sized for introducing of a work object, especially a pin and ring deposit assembly. The oriented jets directed away from the access portal, convey fluid against the devices to be cleaned that can dissolve coatings
25 or contamination. The entry manifold enables injection of fluids for dissolving, washing and drying that can be sequenced without moving the parts being cleaned. The system easily interfaces with a logic system or computer to achieve automated cleaning action. The system is
30 particularly well suited for microbiology and gene research deposit assemblies that are arranged in high density to produce microarrays.

ARRAYER

The gantry of an arrayer, now to be described, can
35 carry one deposit head, a cluster of independently operable single pin heads, or a multiple pin head of the various

designs described above. Combinations of these are also possible.

Fig. 6 is a perspective view of a slide preparation machine for preparing microscope slides or other substrates such as delicate soft or porous membranes carried on rigid supports. Its function is to rapidly deposit a high density array of fluid dots of different compositions on a number of identical substrates, employing the microdot technology. As shown in Fig. 6, there are a number of 96 well supply plates 31, serving as the central fluid source for resupply of mobile fluid storage devices, and a cleaning station CL.

Horizontal base plate 200 provides a support structure to hold the operating components. Fastened to base plate 200 are vertical sub plates 210, 220, 230 and 240. Fastened to these plates is a dual axis motion system 250, comprising X and Y axis devices 260, 270 for providing X and Y motions, in a parallel plane.

The guide rails of the X and Y axis devices, 260, 270 are parallel to base plate 200, to carry deposit cluster 28 in X,Y motions in a plane parallel to base plate 200.

The X axis device 260 is a commercial device available from Adept of Japan. It moves at a high rate of speed in a controlled manner using a rotary servo motor with a drive screw and a shaft position encoder, employing digital and analog technology. Carried by X-axis device 260 is an orthogonally arrayed Y-axis device 270, which is a smaller version that operates in the same manner as the X-axis device.

The deposit cluster 28 comprises eight deposition mechanisms, ganged together on a mounting structure. These devices may be in accordance with the various structures shown.

After a deposition sequence is complete, the X and Y terminal drives the cluster of depositing elements to the cleaning station CL. In some embodiments they may be passed over the wells from which the fluid originated or other

receptacle and subjected to air blast as by the venturi passage of the cleaning block described, to dislodge excess fluid, or excess fluid may be removed by abrupt stopping of rapid downward movement to dislodge excess fluid.

5 The fluid removal station according to Fig. 7 is a schematic version of the arrangement of Fig. 8, where air flow removes remaining fluid from the pins and rings. The array of pins and rings is purged of remaining fluid by air blast and then by warmed air (or other gas). The array of
10 pins and rings is washed and rinsed by liquid or aerosol streams and dried, while remaining stationary.

As an alternative to the top access multiple venturi scrub chamber in the system of Fig. 6, the array of pins and rings of a cluster 28 may be held over a vessel of water for
15 cleaning, in which the water level is maintained and a pump constantly replenishes the water. Blotting paper or a cellulose sponge may be provided against which the pin and ring are blotted for fluid removal or drying. By considering the relative clumsiness of such techniques, one
20 gains a better understanding of the significance of the venturi chambers described.

The control system of the arrayer of Fig. 6 has controls for the X and Y axis movement and also home center for the X and Y axis. The actual position of the carriage
25 that the lead screw is driving is sensed so the carriage can be driven home and then the counter is initialized so precision motions can be made along both the X and Y axes. As previously described, each deposition head may have two motors, a pin drive motor and a ring motor, which are
30 commanded from the control computer.

For deposit on microscope slides including slide-like rigid members carrying delicate, soft membranes, the slides are fastened to the table, or placed in register with guides in a known position. Features on the base plate of
35 the machine locate the slides in predetermined orientation.

For use in high volume production contexts, the

system described in the foregoing figures preferably employs a rapidly moving, laterally constrained, axially compliant pin as shown in Figs. 4 and 4A, in a deposit cycle of less than 0.1 second, in which impact and vibration is minimized, with the natural frequency of the system more than 10Hz, in many cases preferably 20Hz, a pin contact pressure of less than 1.0 gram, preferably less than 0.5 gram in many cases preferably about 0.3 gram, and the system employing damping.

Each pin as shown in Fig. 4A is mounted in its own mounting tube by threading into a header plate, and can be readily individually removed and replaced for service or for providing pins or different sizes appropriate to different protocols.

Pin pressure on the substrate is light, and fluid splatter or separation conditions are thus avoided, despite the high speed of action, so that dots of fluid of uniform shape are consistently formed at precisely controlled positions, even on soft or fragile receiving surfaces, thus providing more accurate arrays, and as well, keeping the nearby environment clean and free of tapping or impacting elements.

In the deposit action of the deposit pin, by raising the pin after contact of the drop on the substrate, the combined effects of inertia of the stationary fluid and surface tension (and of gravity, when depositing downwardly, which is normally preferred) act upon the drop of fluid to overcome the force of surface tension exerted by the lifting pin. The fluid drop preferentially stays with the surface of the substrate, and the pin, substantially devoid of fluid, is free to be replenished and move rapidly to its next destination.

As the volume of the fluid is accurately specified by use of standard sizes of pin, and standard conditions, and the position of the pin is precisely constrained as by the mounting tube of Fig. 4A, spots, dots and microdots of consistent size and precise location are produced, that

enable an improved degree of quantification of observed results. In particular, this is of importance in support of the new field of quantified fluorescence microscopy.

5 D. Examples of Novel Methods of Use

The systems described are useful with any native fragment of DNA, or pre-synthesized oligonucleotide of any length. There being no restriction as to chemicals, any non-photoreactive chemical as well as photoreactive
10 chemicals can be employed. Likewise dyes that are useful to detect presence or absence of DNA may be selectively deposited in registry with previously deposited spots or microdots of biological material, and vice versa. Indeed, in one example, the accuracy of the spotting technique
15 employed here, is capable of spotting standard fluorescing sample dots that can be employed as a calibration standard for the instrument to support quantified fluorescence microscopy.

Among the many biological materials that may be
20 spotted at high speed are fragments of nucleic acids, e.g. DNA, RNA or hybrids such as PNA (peptide nucleic acid), PCR (polymerase chain reaction) products, cloned DNA, and isolated genomic RNA or DNA, as well as synthetic analogs.

Also included are restriction enzyme fragments, full
25 or partial length cDNA, mRNA or similar variations thereof, proteins such as protein receptors, enzymes, antibodies, peptides and protein digests; carbohydrates; pharmaceuticals; microbes including bacteria, virus, yeast, fungi, and PPLO; cells and tissue fragments; lipids,
30 lipoproteins, and the like; plastic resin polymers, small particulate solids in suspension, etc.

The deposition system may also be employed to deposit catalysts, reagents and encapsulants upon previously deposited material of any of the types above or, as
35 mentioned below, to create an array of sites or micro-wells for later reaction or growth of such material, or to assist

in neutralizing or cleaning the deposit or reaction sites, as in the case of highly toxic or virulent substances. The high effectiveness and containment provided by the cleaning system enables working with virulent or dangerous materials that can enable safer diagnostics and disease control, and can extend the range of useful reactions that may be investigated.

The most basic use of the arrayer is to create high density arrays of nucleic acid on a porous or solid, flat surface, generally a microscope slide or slide-like support.

Deposit is possible on fragile or soft surfaces such as microporous membranes or gels, glass cover slips, plastic surfaces, and wells of a microplate, or any substrate, which may be previously coated or derivatized, and serve as a recipient surface.

In particular, membranes and gels are desirable to enable high density analysis with automatic equipment, using materials familiar to the field, on which much of the important, historical data has previously been acquired. Also, deposit on fragile glass cover slips is desirable as they are thinner than microscope slides, easier to maneuver, and when a beam of light is transmitted through them for transmission microscopy, better light capture occurs because the slip is thinner and less light absorptive. The system has the capability of spotting on plastic surfaces without scarring or deforming the surface.

In addition to applicability in bioresearch and clinical diagnosis, the deposition and instrument cleaning system has applicability in the chemical laboratory, e.g. to analyze fluids, such as for water quality, or to experiment with resins, for instance polymerization reactions, to conduct experiments in small quantities of many different varieties, e.g. to determine optimum ratios and optimum selection from a host of slightly varying examples. The range of usefulness is broad with application to the new, popular paradigm of a large number or simultaneous

experiments based on small quantity samples, different temporal sequences, different kinetics of reaction, and different mixtures. In all of these cases, the deposit and cleaning system is a precise way of manipulating small amounts of liquid, solids in liquid suspension and cells in suspension, under controlled and safe conditions.

Deposition with the systems described leads to rapid and precise observations, reduction in the number of trials for a given experiment and improvement in the statistical significance of the data. Cost savings and improved experimental procedures can be realized. Quantification of results at accuracies heretofore unknown may be attained by consistent and precise dot formation that enables improved signal-to-noise ratio in detection, when sensing the difference between, e.g., the fluorescence of a deposited spot and the immediately adjacent background surface of the substrate.

The system is useful in many environments due to the attributes of the deposit and cleaning apparatus, and the techniques by which movement and control is effected.

In another method employing the deposit and cleaning system, an etchant fluid is provided in a local reservoir ring. The pin of the deposit pin distributes the etchant in tiny, precise spots or microdots in a desired array across a reactive substrate surface. For instance, for forming micro-wells for containing fluid, the device deposits an acid such as hydrochloric acid in an array of small dots upon a silicon substrate. An etching reaction occurs, and the substrate is then neutralized and washed, to produce a corresponding array of small wells, after which the tools of the arrayer may be washed of etchant without risk of contamination or harm to the adjacent activities.

Arrayers as described can also be used for color printing of fabrics, paper etc., where the 96 well plate holds different color inks or dyes. The area to be printed is the entire reach of the gantry less the color source and

washing station.

The arrayer can be used to generate a single printed circuit board, e.g., prototype boards, or boards for limited volume production, where the machine is employed to deposit
5 varnish or photoresist or other protective coating material to define the regions of the copper clad or other substance which need to be preserved from acid etching. Likewise the arrayer may be employed to deposit photoactive substance for production of "biological" deposits using lithographic
10 techniques, all with the assurance that the deposit elements will be cleaned to avoid cross-contamination.

A variation of the spotter mechanism employs, in a fashion analogous to that of a modern milling machine, a set
15 of interchangeable heads having different capabilities. Under computer control, an X-Y carriage of the system is moved to select a desired head that is carried across the substrate to be cleaned and perform its function. In some instances the device selected may be a sub-reservoir ring
20 from a set of such rings that have different internal diameters or are formed of different wire or ribbon sizes, or are of different sizes to enter different wells, etc. These provide a variety of carrying capacities for fluids of different viscosities or for use with deposit pins of
25 different sizes. Likewise, different sizes of deposit pins can be selected from a set of pins to vary the size of the spot to be deposited. Heads can also be selected that provide other devices for preparing for or conducting experiments or for the production of reference or diagnostic
30 well plates and slides.

In some cases the selection and use of devices can be conducted under complete computer control to enable automatic performance of a multi-task experiment un-attended by the technician, in which the tools or devices are
35 subjected to automated cleaning, e.g., with the system of Fig. 8, during the regular course to avoid contaminated

experiments.

In addition to depositing spots of fluid upon a standard microscope slide, and upon porous or soft membranes and other delicate substrates, it is possible and
5 advantageous to deposit spots on substrates of significantly larger area and on other substances and on surfaces having special formations, for instance upon substrates having micro-cavities that have been formed by the instrument
10 itself, by one of the techniques described above. Plates delivered with the micro-cavities preformed in the substrate may also be used, and aligned for deposit of fluid by automatic controls of the instrument, or the control system of the unit is advantageously provided with a vision system that "reads" the location and pattern of the array of micro-
15 wells, and adjusts itself automatically or under operator control to accurately deposit dots of fluid in wells. Likewise a vision system can be employed to identify different types of cleaning chambers that have been installed, e.g. by bar code identification to ensure that
20 each device to be cleaned enters a suitable chamber into which it fits and which has appropriate features for cleaning imaging special features of the tool or other device.

25

F. Conclusion

In the various ways described, a large array of fluid deposit sites may be established and managed in a precise, repeatable manner that employs the same concentrations or reactions or precisely varied
30 concentrations and reactions, under conditions that prevent contamination and enable high speed or automatic action. This may be done to enable examination, to promote reaction or growth processes in biotechnology, life sciences, chemistry, pollution detection, process control and in
35 industry in general.

Thus, beyond an instrument for low-cost preparation

of microscope slides and membranes for biotechnology research, there has been contributed a universal and widely variable set of systems, instruments, methods and products that can advance research and industry.

5 Numerous other embodiments not described in detail here can apply the principles described to particular applications and are within the scope of the claims.

What is claimed is:

1. An apparatus for depositing an array of spots on a receiving surface, comprising:

a deposit device, including a drop-carrying surface, and a fluid source cooperatively arranged to deposit a spot
5 on a receiving surface; and

a cleaning device constructed and arranged to clean said drop-carrying surface by employing a flow of cleaning fluid.

10 2. The apparatus of claim 1 wherein said cleaning device includes a fluid jet constructed and arranged to blow said cleaning fluid.

3. The apparatus of claim 1 wherein said cleaning
15 device includes a fluid jet constructed and arranged to blow said cleaning fluid at least partially along a length of said deposit device toward said drop-carrying surface.

4. The apparatus of claim 3 wherein said drop-
20 carrying surface is located at least partially within a confinement chamber.

5. The apparatus of claim 1 wherein said deposit device has a pin-like structure with said drop-carrying
25 surface disposed in a distal end of said pin-like structure.

6. The apparatus of claim 4 wherein said drop-carrying surface has a diameter less than 375 micron, preferably less than 300 micron, preferably between about 15
30 and 250 micron.

7. The apparatus of claim 5 wherein said pin-like structure includes sides that intersect with an end surface that defines a rim of said drop-carrying surface.
35

8. The apparatus of claims 5 further including a

mobile supply device, associated with said deposit device, and arranged to supply material for deposition of said array of spots.

5 9. The apparatus of claims 8 wherein said mobile supply device includes a mobile local supply device arranged to move partially with said pin-like structure.

10 10. The apparatus of claims 9 wherein said cleaning device is constructed and arranged to deliver said cleaning fluid at least partially to said mobile local supply device.

15 11. The apparatus of claims 9 wherein said mobile local supply device includes a ring-like structure located near said drop-carrying surface.

20 12. The apparatus of claims 11 wherein said cleaning device is constructed and arranged to deliver said cleaning fluid at least partially to said ring-like structure and said drop-carrying surface.

25 13. The apparatus of claims 8 wherein said deposit device and said mobile supply device are movable together to said cleaning device in response to a control system.

30 14. The apparatus of claims 9 wherein said mobile local supply device includes an annular member through which said deposit device operates by a relative motion of said drop-carrying surface, and said cleaning device includes a nozzle for directing a flow of said cleaning fluid past said annular member and said drop-carrying surface.

35 15. The apparatus of claim 8 further including a drying device constructed to discharge drying fluid.

16. The apparatus of claim 2 or 3 wherein said

fluid jet includes a circular nozzle constructed to emit a conical flow of said cleaning fluid.

17. The apparatus of claim 2 or 3 wherein said
5 fluid jet includes an annular nozzle constructed to emit a flow of said cleaning fluid.

18. The apparatus of claim 2 wherein said fluid jet
is also constructed to drying fluid.
10

19. The apparatus of claim 18 wherein said fluid
jet includes a circular nozzle constructed to emit a conical
flow of said cleaning and drying fluid.

20. The apparatus of claim 18 wherein said fluid
jet includes a circular nozzle constructed to emit a conical
flow of said cleaning and drying fluid.
15

21. The apparatus of claim 19 or 20 further
20 including a reservoir for receiving said cleaning and drying fluid.

22. The apparatus of claim 21 further including a
vacuum pump associated with said reservoir.
25

23. The apparatus of claim 2 or 3 further including
a reservoir for receiving said cleaning fluid emitted from
said fluid jet.

24. The apparatus of claim 23 further including a
vacuum pump associated with said reservoir.
30

25. The apparatus of claim 18 including at least
two fluid paths associated with at least two fluid
35 reservoirs and connectable to said fluid jet.

26. The apparatus of claim 1 including a control system arranged to control a flow velocity of said cleaning fluid.

5 27. The apparatus of claim 1 including a control system arranged to select a type of said cleaning fluid.

28. The apparatus of claim 27 wherein said control system is arranged to select said type of said cleaning
10 fluid at a source location.

29. The apparatus of claims 1, 2, 3, 8, 9 or 14 wherein said cleaning fluid is selected from one of the following compressed gas, high pressure liquid, aerosol and
15 heated gas.

30. The apparatus of claims 1, 2, 3, 4, 5, 8, 9 or 14 including at least four said deposit devices and including a mechanism for moving each said deposit device
20 independently toward and away from the receiving surface to deposit respective drops at respective deposit locations on the receiving surface.

31. The apparatus of claims 1, 2, 3, 4, 5, 8, 9 or
25 14 including at least four said deposit devices and including a mechanism for moving said deposit devices simultaneously, relatively, toward and away from the receiving surface to deposit respective drops at respective deposit locations on the receiving surface.

30

32. The apparatus of claim 31 wherein said deposit devices are mounted on a common support that is driven by a common driver to deposit respective fluid drops on the receiving surface.

35

33. The apparatus of claim 31 wherein each said

deposit device is associated with a respective storage ring, the storage rings being mounted on a common storage support driven by a common storage drive.

5 34. The apparatus of claim 8 wherein said mobile fluid storage device that is movable relative to an array of deposit locations, said mobile supply device being constructed and arranged to resupply the deposit device at various locations along said array, preferably the deposit
10 device and the mobile storage device being constructed to supply drops to the deposit device in the immediate vicinity of the deposit locations for respective drops and preferably being coupled for transverse motion relative to the array and decoupled for movement of the deposit device toward and
15 away from the receiving surface.

 35. A method of depositing a biological material on a substrate, including:
 mechanically lowering a pin-like structure including
20 a drop-carrying surface to a substrate and thereby depositing by contact a drop of biological material;
 moving said pin-like structure to a cleaning station; and
 emitting a flow of cleaning fluid toward said drop-
25 carrying surface.

 36. The method of claim 35 including collecting at least a portion of said emitted cleaning fluid in a confinement chamber.

30

 37. The method of claim 36 including pumping fluid from said confinement chamber.

 38. The method of claim 35 wherein said emitting
35 includes directing said cleaning fluid along said pin-like structure toward said drop-carrying surface being surrounded

by a ring-like structure forming a mobile local supply device.

39. The method of claim 35 including emitting a
5 drying fluid after emitting said cleaning fluid.

40. The method of claim 35 providing at least to
fluid reservoirs, and the method including, after said
emitting, switching to a second-mentioned reservoir and
10 emitting fluid from said second-mentioned reservoir.

41. The method of claim 35 further providing
multiple flow nozzles and at least one confinement chamber,
the method including emitting multiple flows of said
15 cleaning fluid through said flow nozzles located at said
confinement chamber.

42. The method of claim 35 including at least one of
the following: compressed gas, high pressure liquid,
20 aerosol, and heated gas.

43. A method of depositing a biological material on
a substrate, comprising:
receiving on a drop-carrying surface of a pin-like
25 structure a first type of a biological material drop;
mechanically lowering said pin-like structure toward
a substrate and thereby depositing by contact from said
drop-carrying surface said biological material drop of said
first type;
30 moving said pin-like structure to a cleaning
station;
emitting a flow of cleaning fluid toward said drop-
carrying surface;
receiving on said drop-carrying surface a second
35 type of said biological material drop;
mechanically lowering said pin-like structure toward

said substrate and thereby depositing by contact from said drop-carrying surface said biological material drop of said second type.

5 44. The method of claim 43 wherein said depositing of said biological material drop of said second type is performed on a location of said substrate that is overlapping with a deposited location of said first type drop on said substrate.

10

 45. The method of claim 43 wherein said depositing of said biological material drop of said second type is performed on a location of said substrate that is different from a deposited location of said first type drop on said
15 substrate.

20

 46. The method of claim 43 wherein both said receiving acts are performed by using a mobile supply device.

 47. The method of claim 43 wherein both said receiving acts are performed by using a local mobile supply device.

25 48. The method of claim 47 wherein said local mobile supply device includes a ring-like structure located near said drop-carrying surface

 49. The method of claim 46 wherein said mobile
30 supply device includes a 96 well plate.

 50. The method of claim 48 wherein said emitting of said flow of cleaning fluid includes directing said flow partially along said pin-like structure past said supporting
35 surface and partially through said ring-like structure.

51. The method of claim 50 wherein said receiving on said drop-carrying surface said second type of said biological material drop includes dipping said ring-like structure into a well of a well plate.

5

52. The method of claim 35 or 43 wherein said biological material includes fluorescing material, an ink, dye, stain or marker, a photoactive material, radioactive material, a varnish or encapsulant, or an etchant.

10

53. A cleaning station for a deposit device constructed and arranged to deposit an array of spots on a receiving surface by carrying material on a drop-carrying surface, comprising:

15

a confinement chamber having a portal sized to receive a drop-carrying surface; and

a flow nozzle arranged adjacent said portal to produce a flow of cleaning fluid directed toward said drop-carrying surface.

20

54. The cleaning station of claim 53 wherein said flow nozzle is located outside said confinement chamber and is constructed to direct said flow of cleaning fluid directed toward said drop-carrying surface generally inwardly into said chamber.

25

55. The cleaning station of claim 53 wherein said flow nozzle is located inside said confinement chamber.

30

56. The cleaning station of claim 53 constructed to use multiple fluids delivered through said flow nozzle.

57. The cleaning station of claim 53 also constructed to deliver through said flow nozzle drying fluid.

35

58. The cleaning station of claims 53 constructed to deliver through said flow nozzle one of the following: compressed gas, high pressure liquid, aerosol, and heated gas.

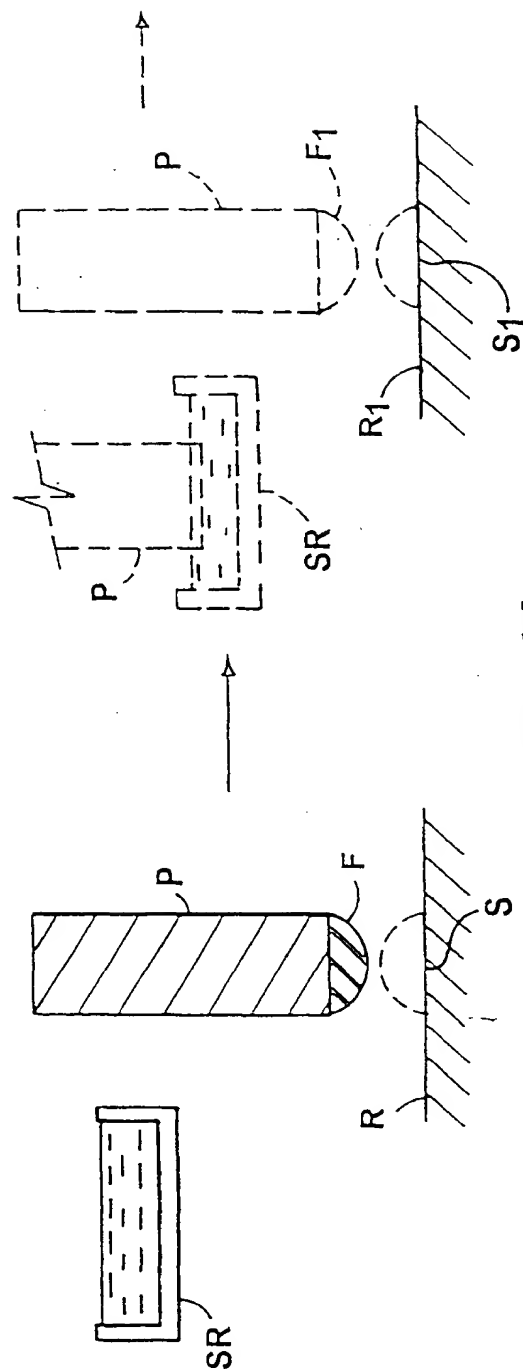
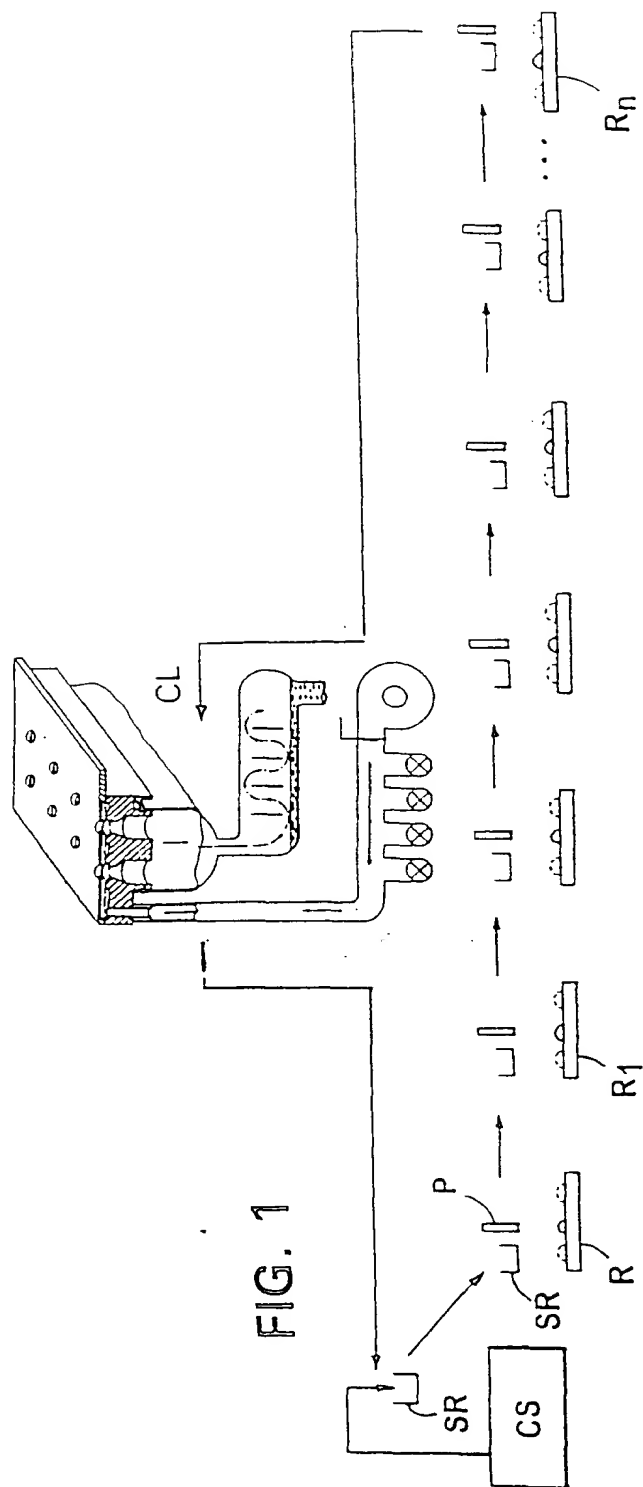
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59. The cleaning station of claim 53 constructed to deliver through said flow nozzle one of the following: a solvent, a rinsing agent, a cleaning agent, and drying agent.

10

60. The cleaning station of claim 53 wherein said deposit device comprises a deposit pin having said drop-carrying surface and at least partially ring-shaped reservoir constructed to receive said pin, said nozzle being constructed and arranged to direct said flow also between said pin and said reservoir toward said drop-carrying surface.

61. A cleaning station for a deposit device comprising a set of separate pin-like structures supported on a common member and constructed respectively to form individual spots on a substrate, a cleaning station defining a confinement chamber having a set of top portals corresponding to the relative location of said set of pin-like structures, at least one actuator mechanism for lowering the respective pin-like structure through the respective portals, and a flow assembly constructed to direct a cleaning flow partially along said pin-like structure toward their distal ends and within said confinement chamber.



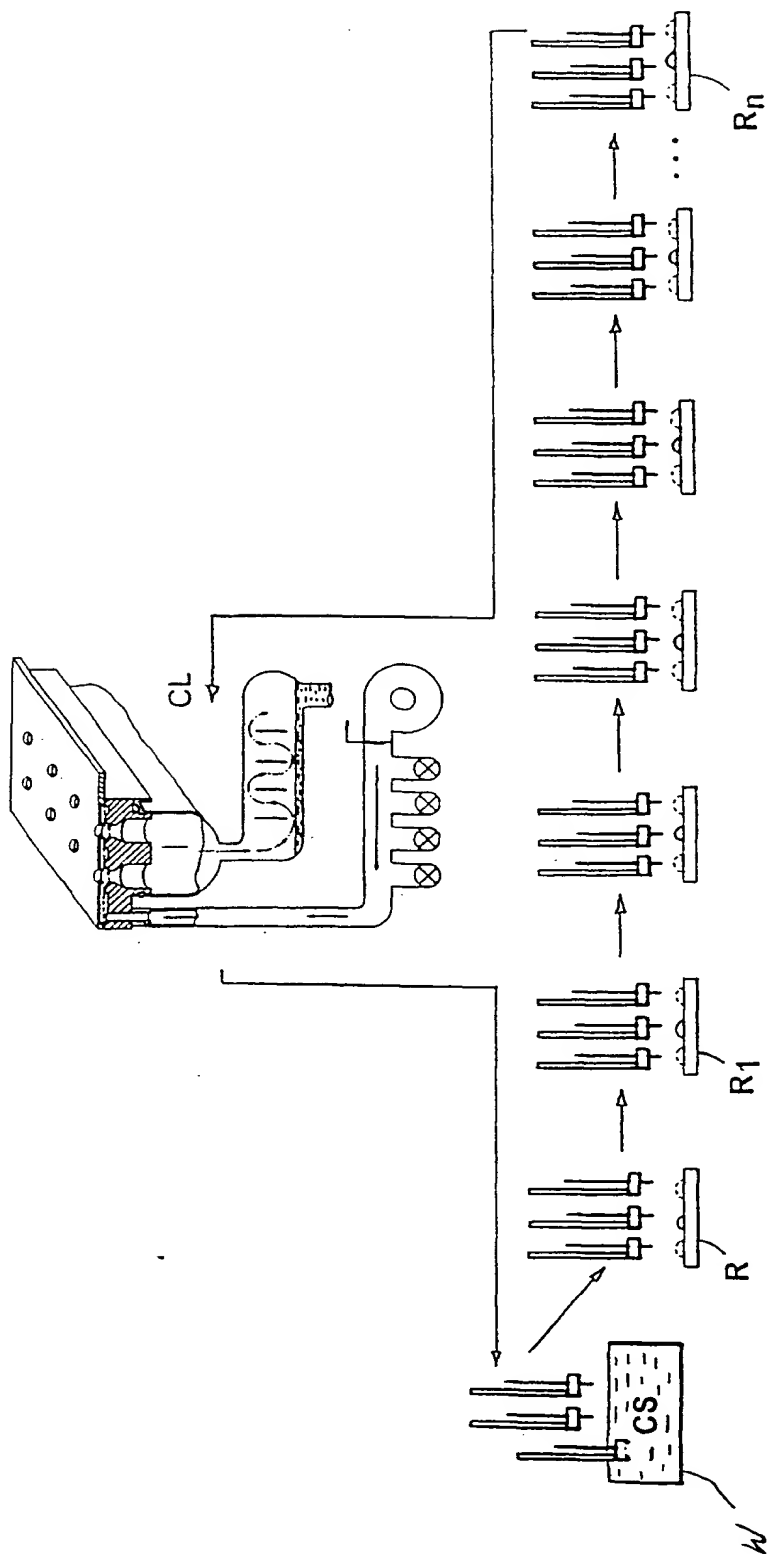


FIG. 2

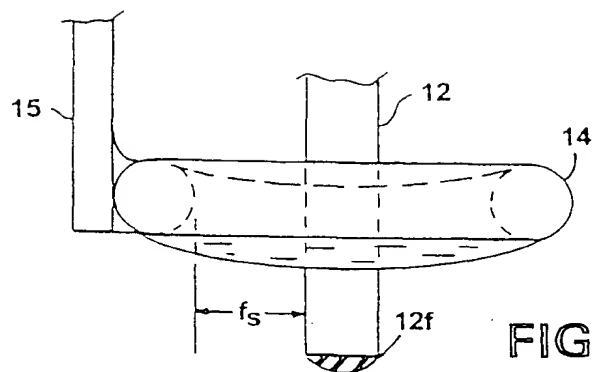


FIG. 2A

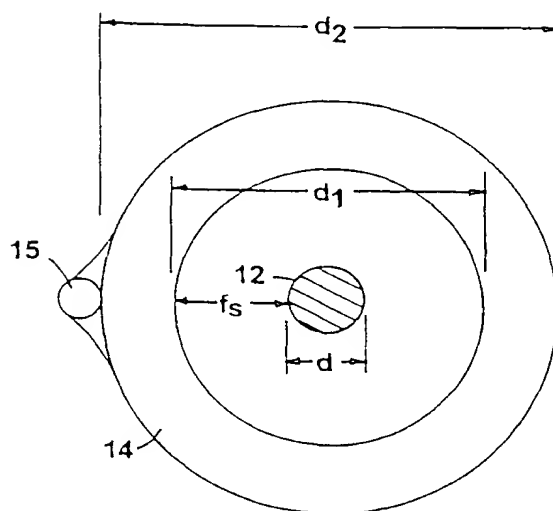


FIG. 2B

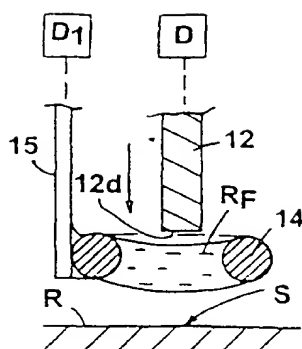


FIG. 3A

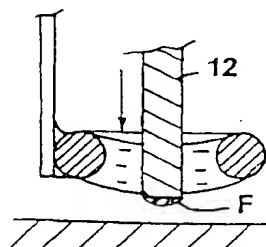


FIG. 3B

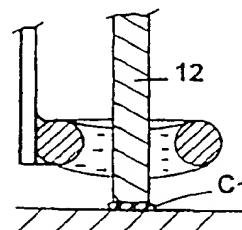


FIG. 3C

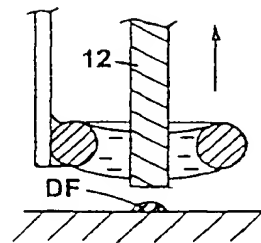


FIG. 3D

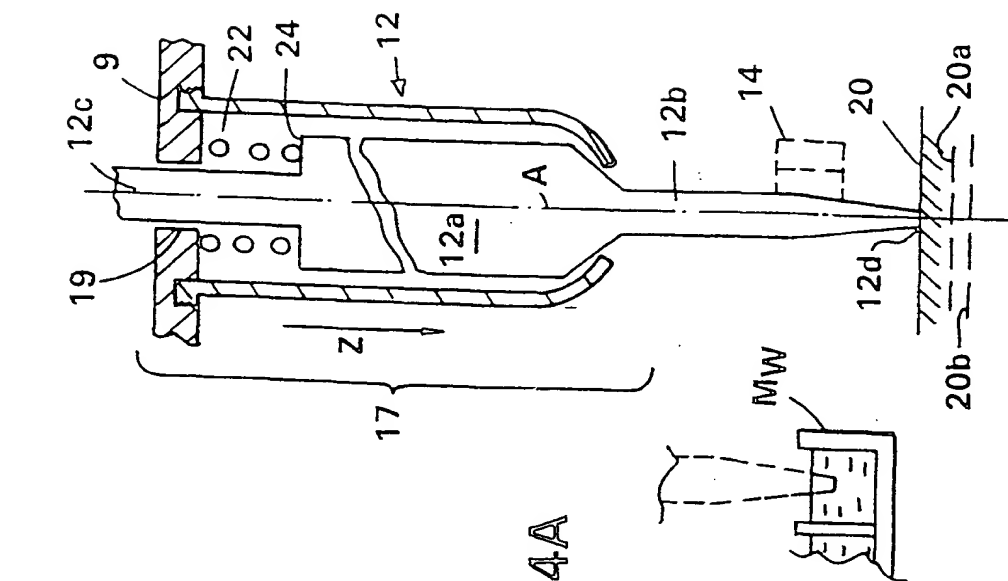


FIG. 4A

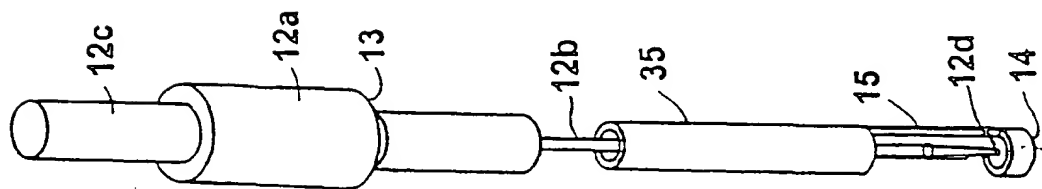


FIG. 4

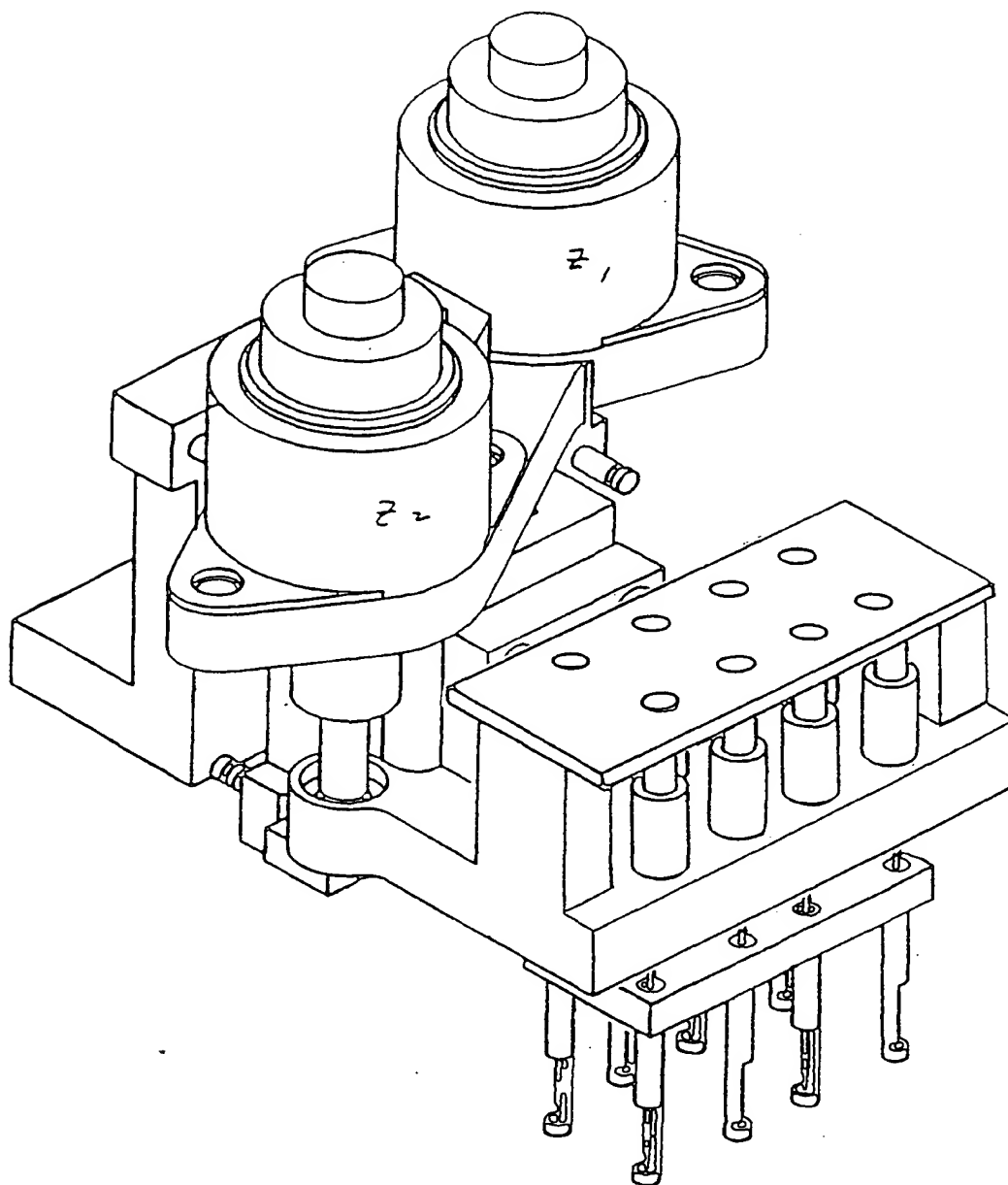
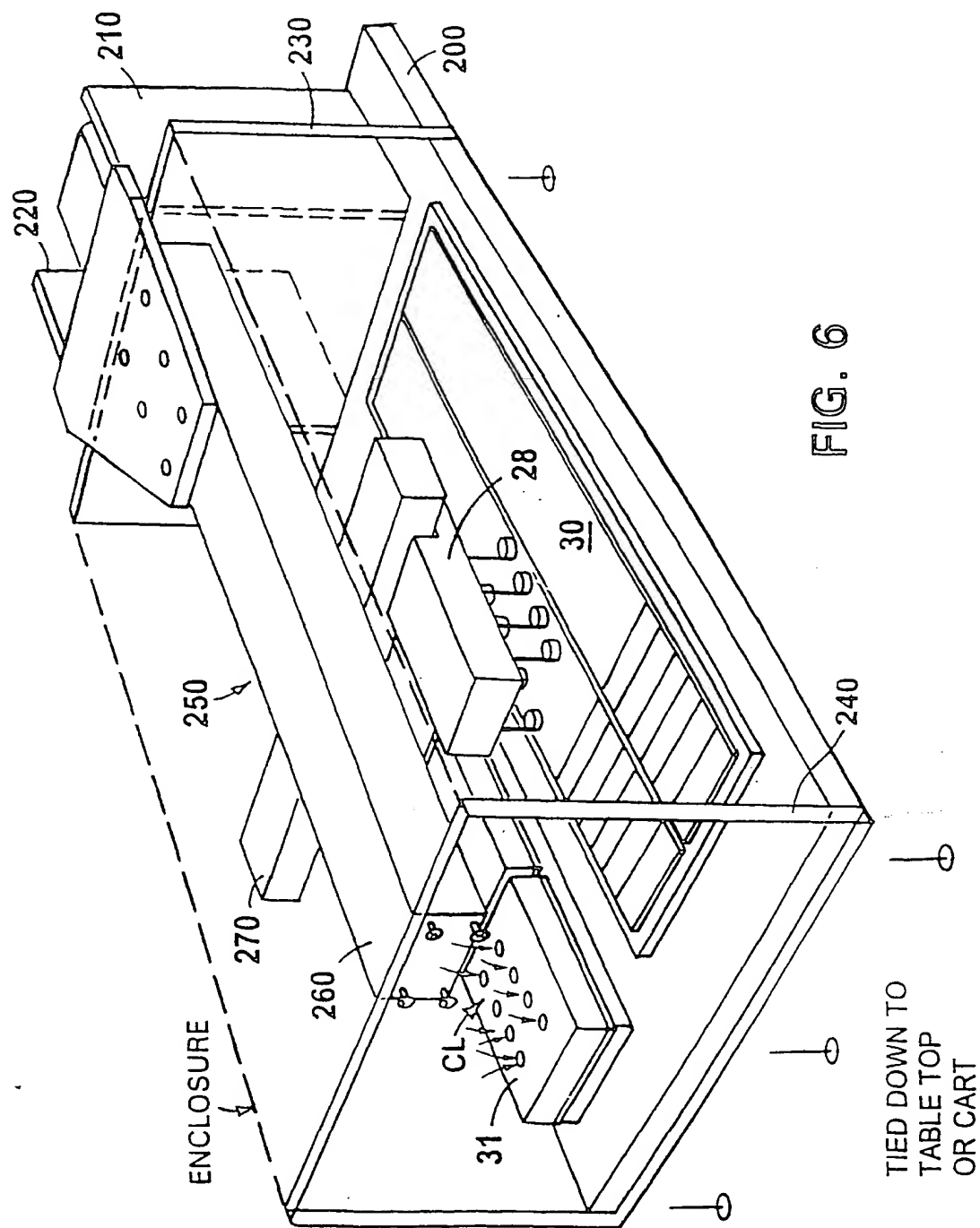


FIG. 5



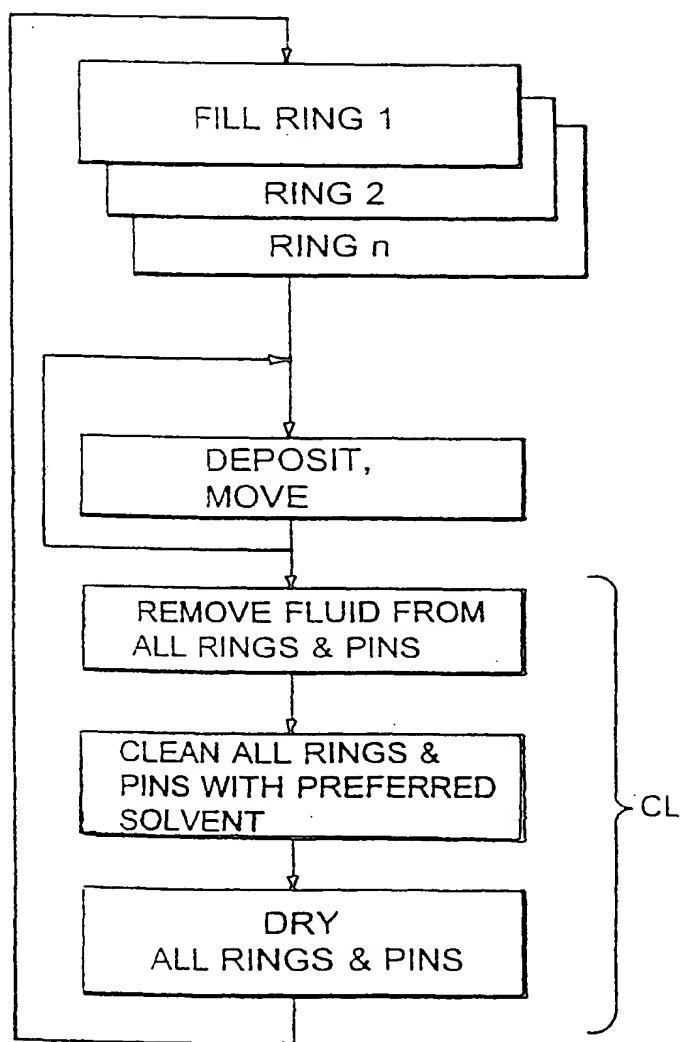


FIG. 6A

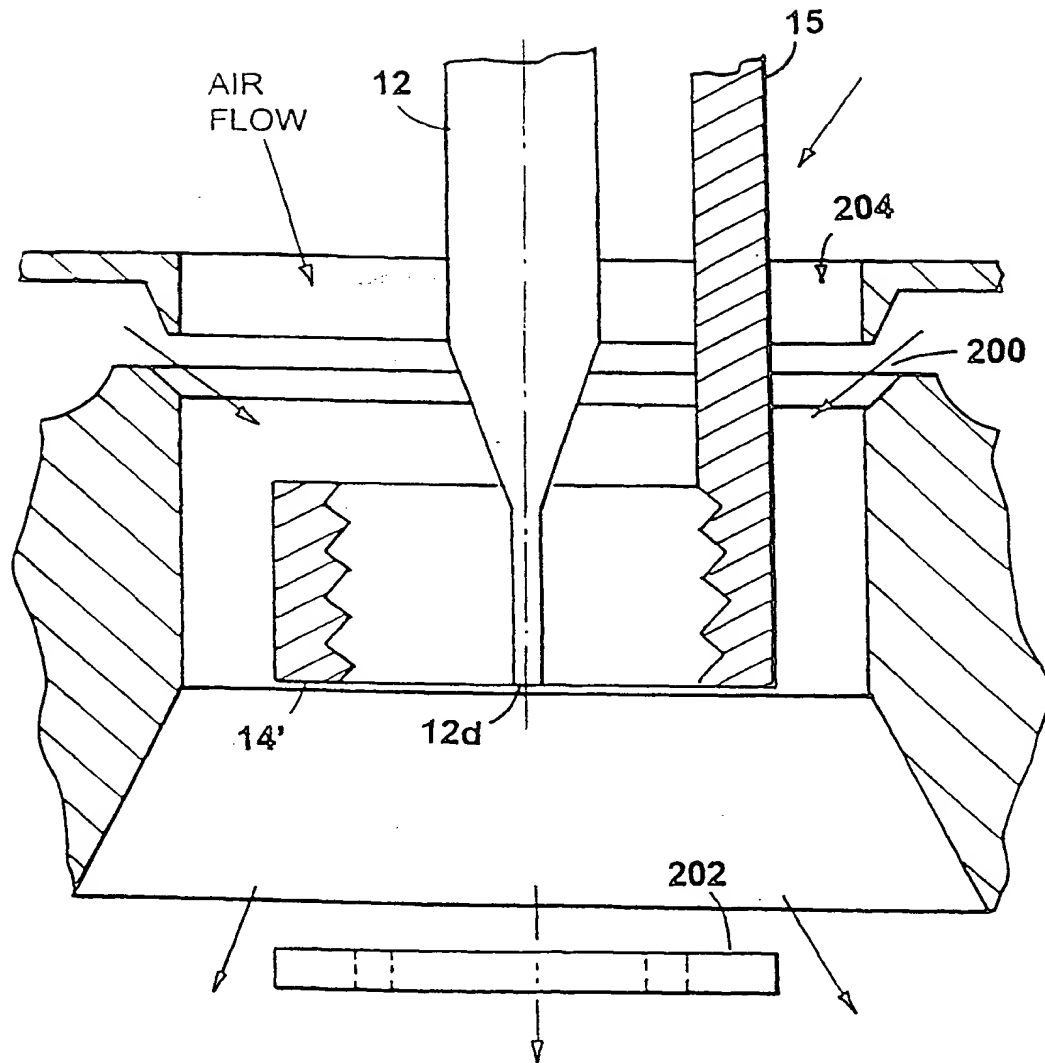
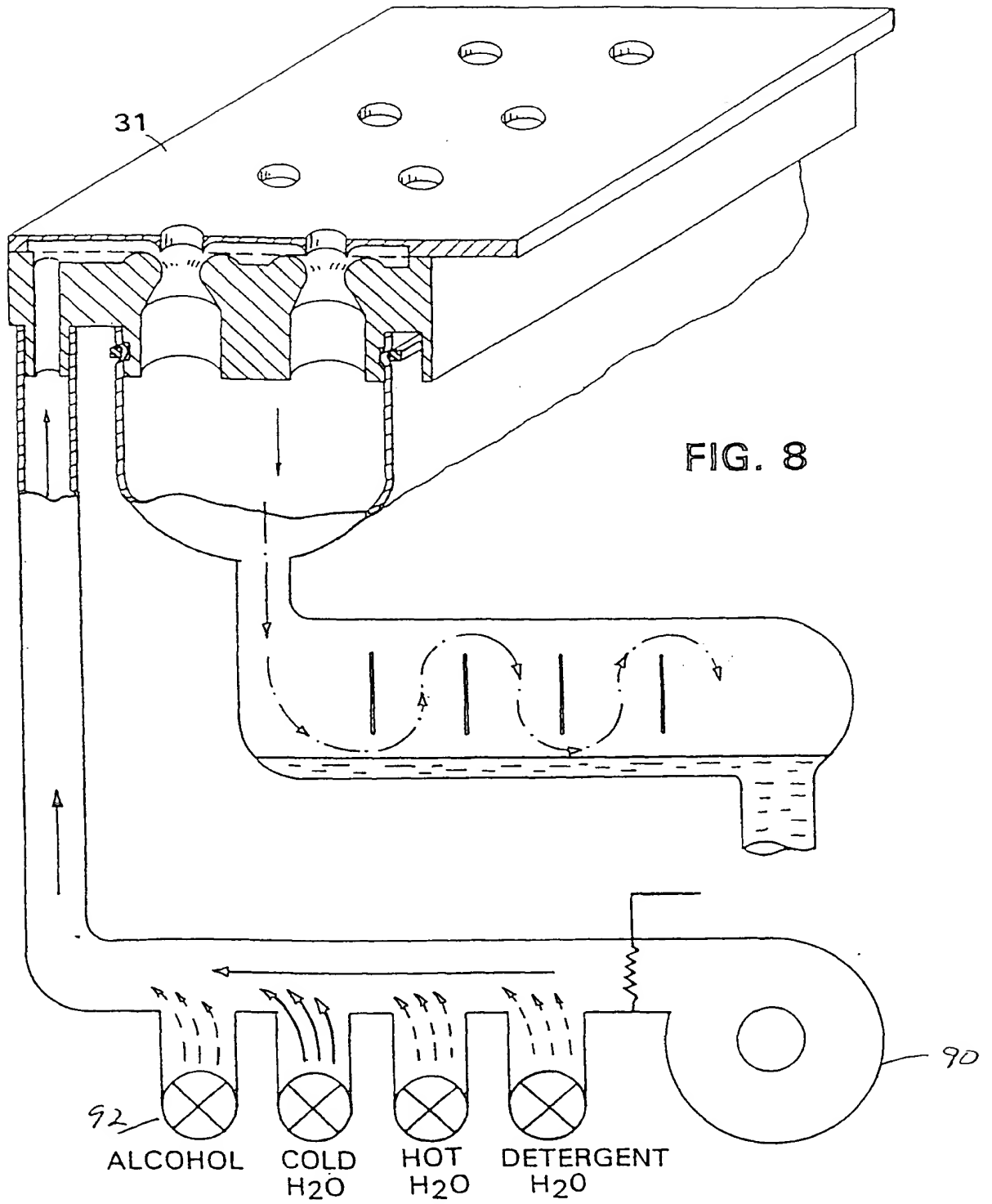
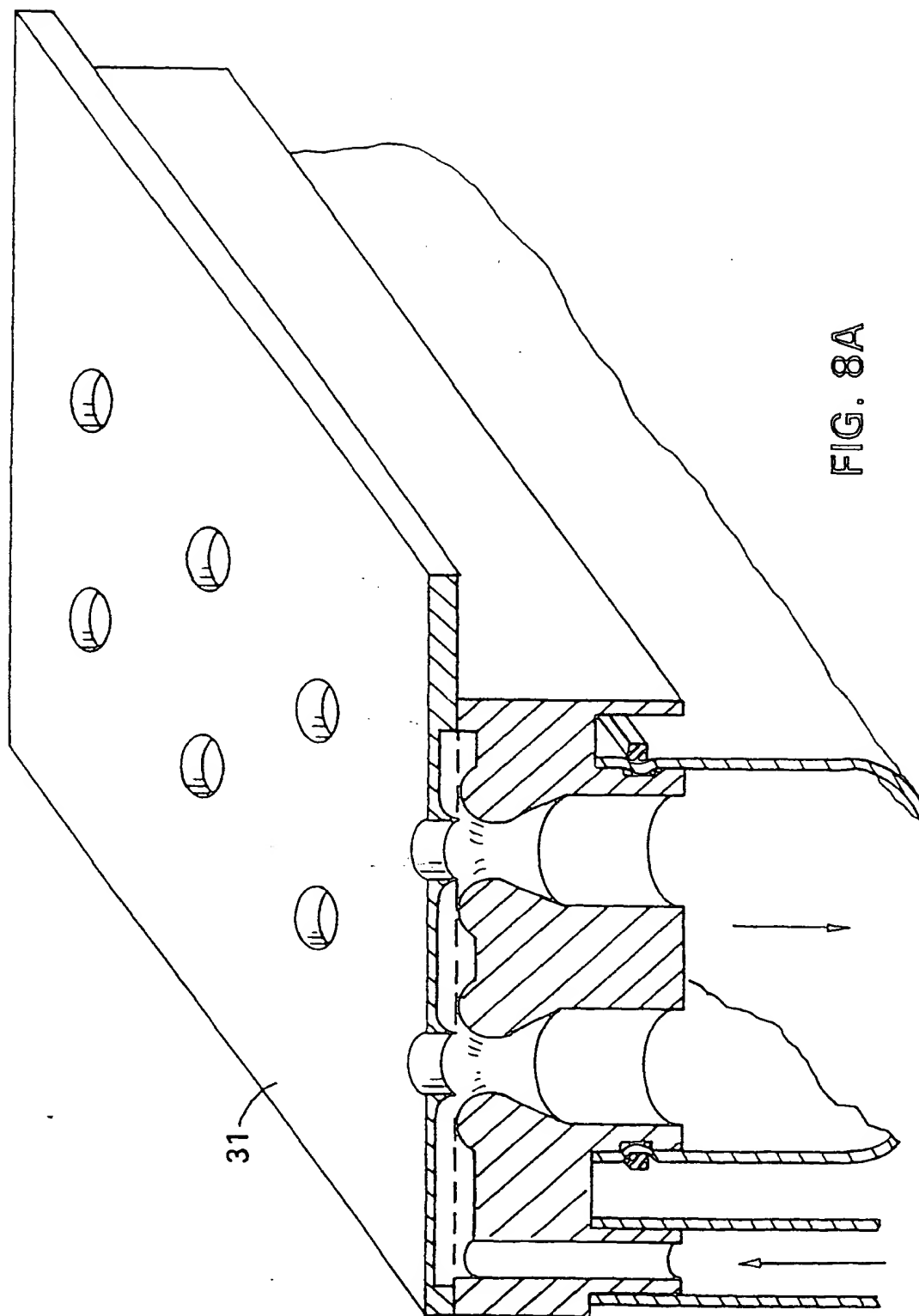


FIG. 7





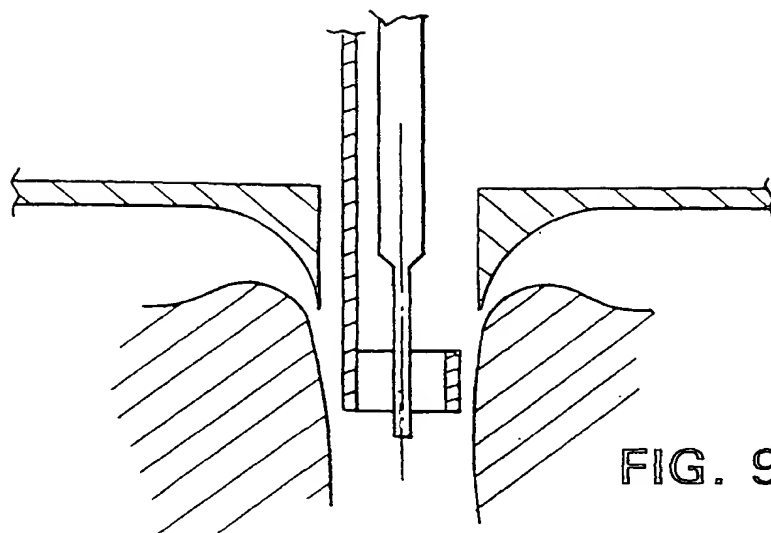


FIG. 9

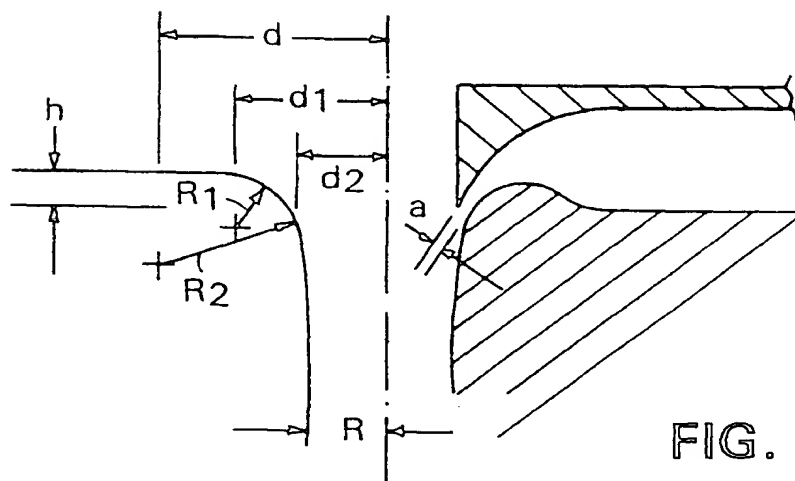


FIG. 9A

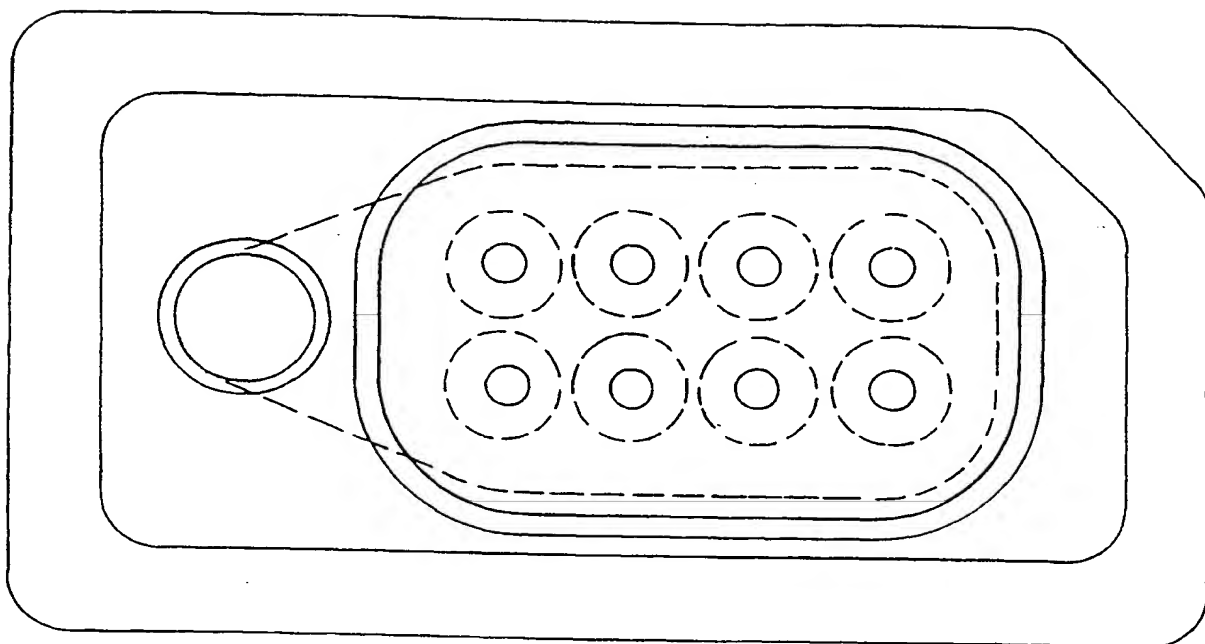


FIG. 10A

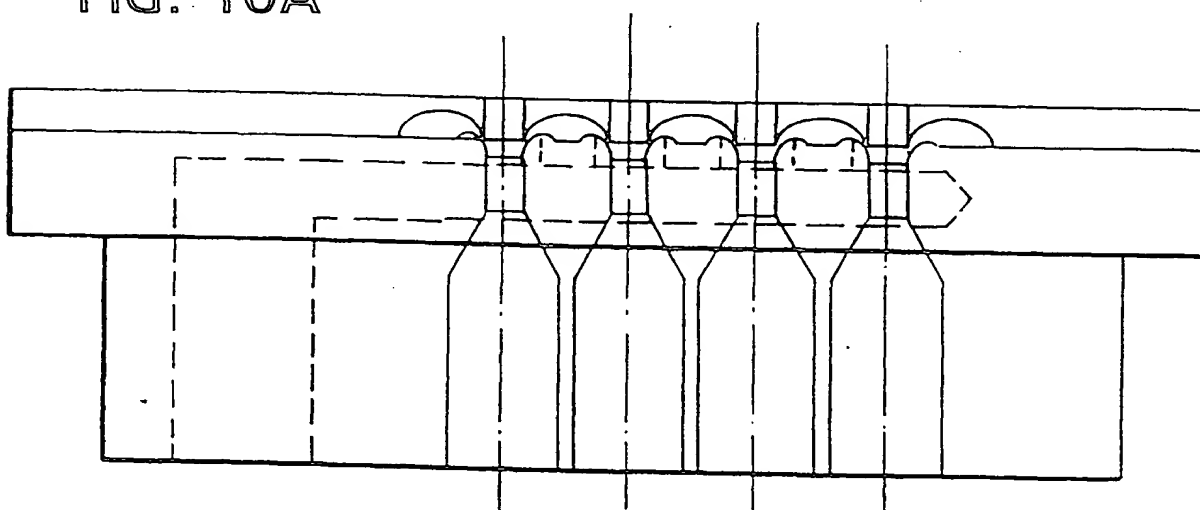


FIG. 10

INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 01/04285

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B01L3/02 B01L11/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 B01L B01J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
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☒ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

15 June 2001

Date of mailing of the international search report

25/06/2001

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INTERNATIONAL SEARCH REPORT

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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| Y | US 5 160 378 A (GEYSEN MARIO ET AL) 3 November 1992 (1992-11-03) column 1, line 24 -column 1, line 28 column 1, line 53 -column 1, line 68 column 2, line 12 -column 3, line 53 | 1,2,5,6, 8,9,11, 13,15, 18,25, 27,29,30 |
| X | figures 1-3 | 53,54, 56-59 |

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Information on patent family members

Int ☐ International Application No

PCT/US 01/04285

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